THAT WE MAY EAT

THE YEARBOOK OF AGRICULTURE 1975

THAT WE MAY EAT

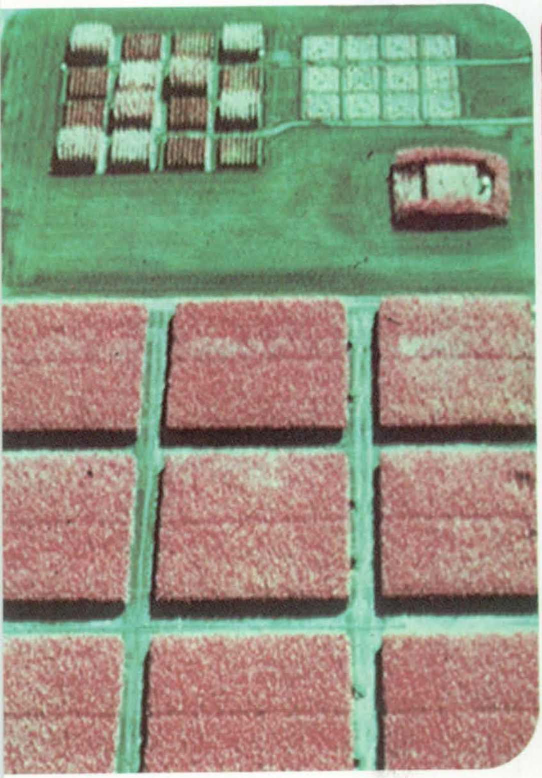
U.S. DEPARTMENT OF AGRICULTURE

American settlers, from the first days in Jamestown to America's last frontier, experimented with crops and livestock that would find a market. The entire farm family (large photo) might go to market with butter, eggs, fruit, potatoes or other products.

Western roundups gradually changed as experiments with better breeds of livestock and controlled grazing insured greater returns to ranchers and higher quality to consumers. Part of rural life in Montana as recently as the 1920's was the horse-drawn school bus (photo at top of page), mounted on a sled in winter and heated with a little barrel stove. In fall and spring the bus rode on buggy wheels.

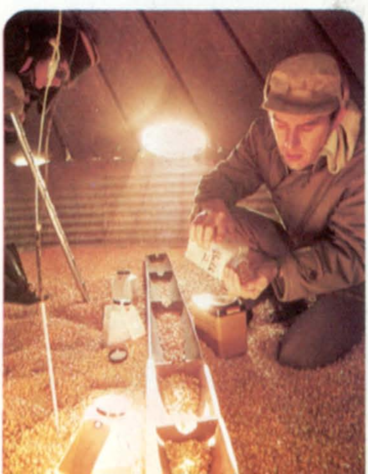
Farmers tried different ways of keeping such perishable foods as meat. One way was to pack ice around the food in an insulated storehouse, saving it for spring or early summer use. Prosperity arrived for many Virginians in 1613, when John Rolfe shipped the first hogsheads of his new type of tobacco to England. During the 1870's, horse-drawn implements gradually replaced hand equipment, as in the haymaking scene.

With the Nation's expansion, State Agricultural Experiment Stations were founded a century ago. Designed to develop scientific ways for improving agriculture, human nutrition, and family living, they provided benefits for all Americans. These color photos reflect station activities and achievements. Infrared photo shows California test plots. Texas scenes at lower right are (top) new Triple Cross cucumber, and station creators of hybrid sorghum at field meeting with other scientists. Opposite page, Illinois test plots and (inset) farmers being taken to plots to see research results.

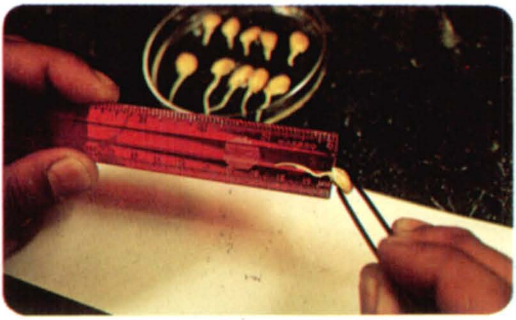


Opposite page: Bottom, seven combines harvesting wheat in Nebraska. Top, high yield Mexican wheat introduced into India, a development of the Green Revolution, to which State scientists contributed.
Bottom right, wheat test plots, and bottom left, students threshing grain nurseries to determine yield, both scenes in Montana. Left, lab work to determine amino acid content of wheat samples, in Nebraska and U.S. Department of Agriculture (USDA) research.

Above, Ohio scientist checks soybean light enrichment. Top, mobile machine, designed by USDA-Illinois researchers, measures three basic biological mechanisms of soybeans, our No. 1 cash crop. Upper right, no-till soybeans in wheat stubble, Kentucky.

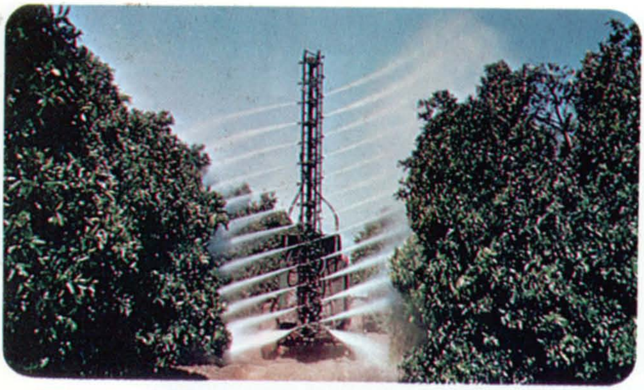


Right, light colored ear of high lysine corn, which has high nutritive value, is compared with a present corn hybrid, in Michigan. Lower right, corn seedlings exposed to Southern corn leaf blight toxins in USDA-Illinois research. Top seedling row is susceptible, bottom row resistant. After two days' growth in toxins, roots are measured. Bottom photo, checking on spread of Southern corn leaf blight. Opposite page, large photo at bottom, Illinois scientist works on blight, a major concern of agricultural producers. Adjoining photo, taking corn samples to determine moisture content, in top of bin, during USDA-Iowa research.



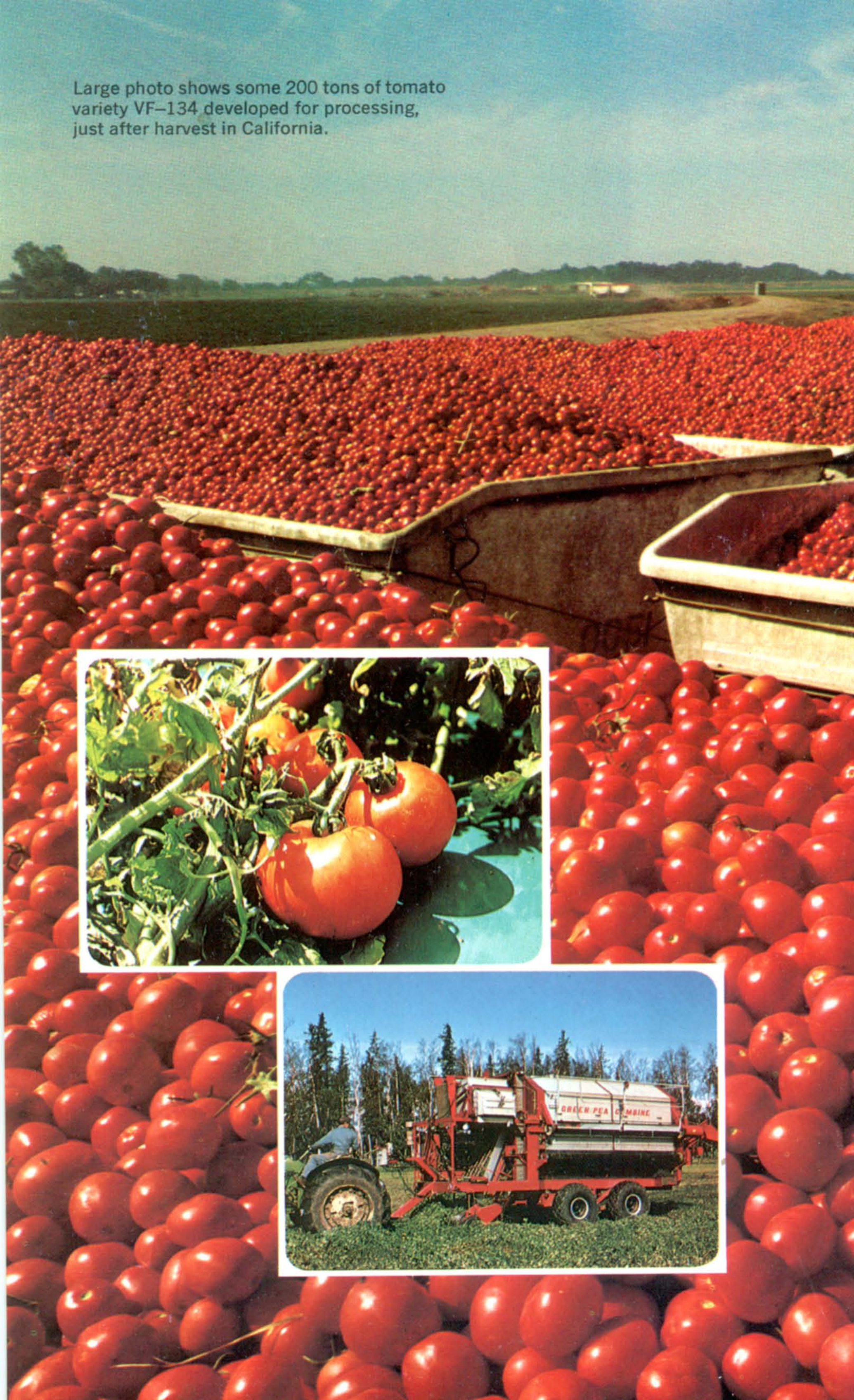
Bottom, dwarf apple trees—vastly improved by regional research—have become "giants" of fruit industry. Below left, comparison shows improved color of Red Delicious apples from growth regulator that speeds up maturity for timely marketing, Alabama. Below right, Golden Delicious apples, Washington. Opposite page: Large photo, applying foam to protect strawberries from frost, Arkansas. New "California" fall-winter pears. Peach variety being tested for mechanical harvesting, Texas. "Benton" strawberry variety developed by USDA-Oregon research.



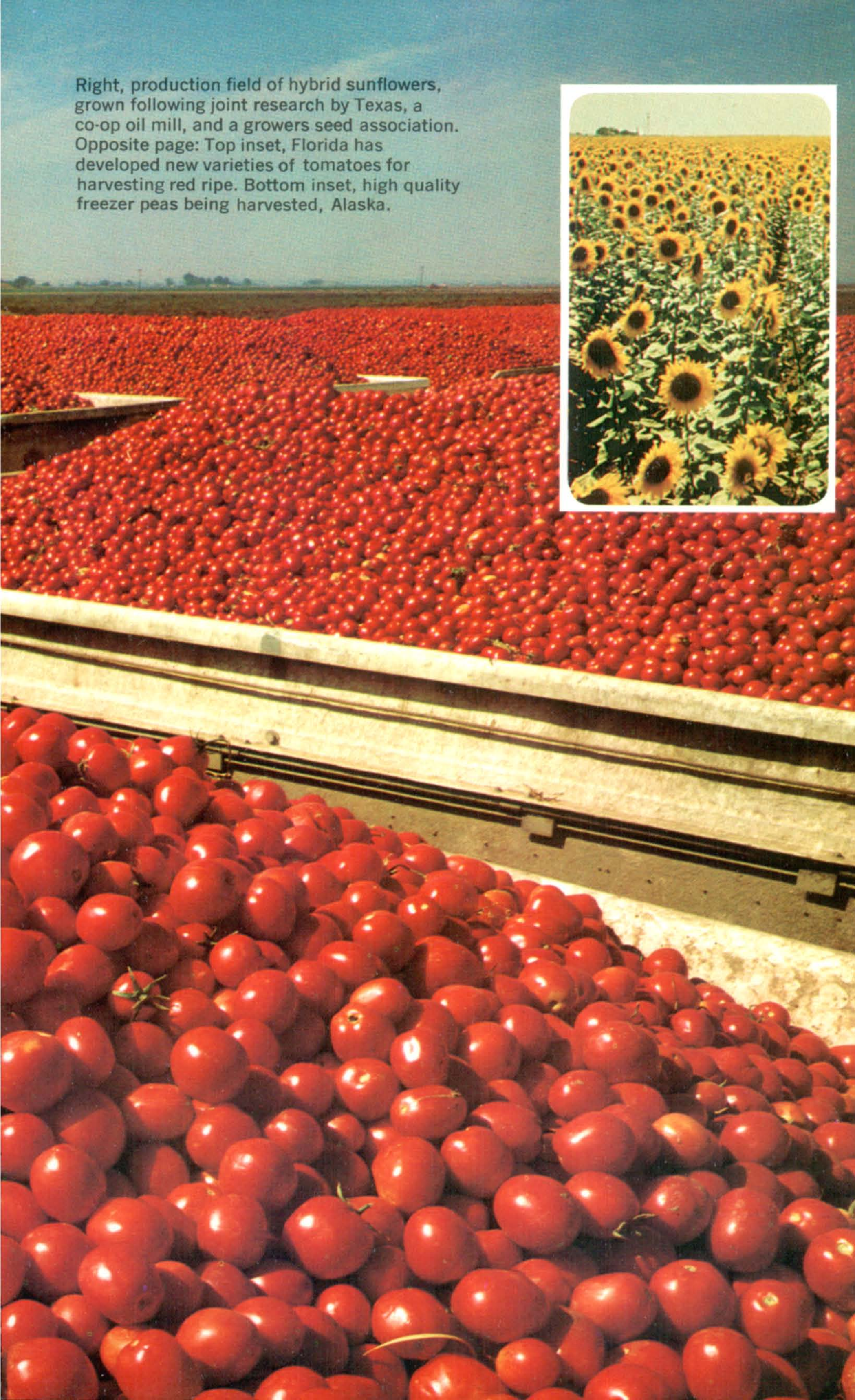



Below, mechanical saws cut off citrus tree tops at an angle to facilitate harvesting, spraying, and entrance of light, Florida. Left, oscillating boom sprayer for applying pesticide in orange groves, California.

Above, Florida has found evaluating root stocks for citrus requires 10 to 15 years of records of yield, quality, and tree vigor. Left, California return-stack heaters meet pollution standards and protect citrus from freezing. Below, harvesting oranges, Florida.

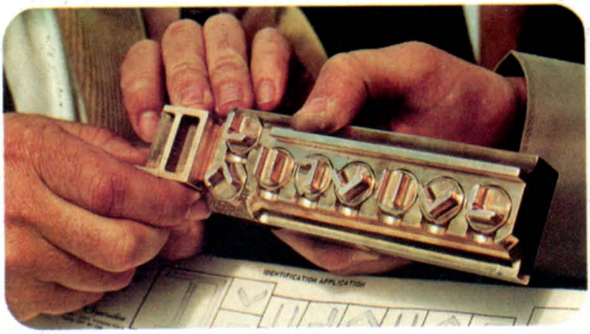


Large photo shows some 200 tons of tomato variety VF–134 developed for processing, just after harvest in California.



Right, production field of hybrid sunflowers, grown following joint research by Texas, a co-op oil mill, and a growers seed association. Opposite page: Top inset, Florida has developed new varieties of tomatoes for harvesting red ripe. Bottom inset, high quality freezer peas being harvested, Alaska.

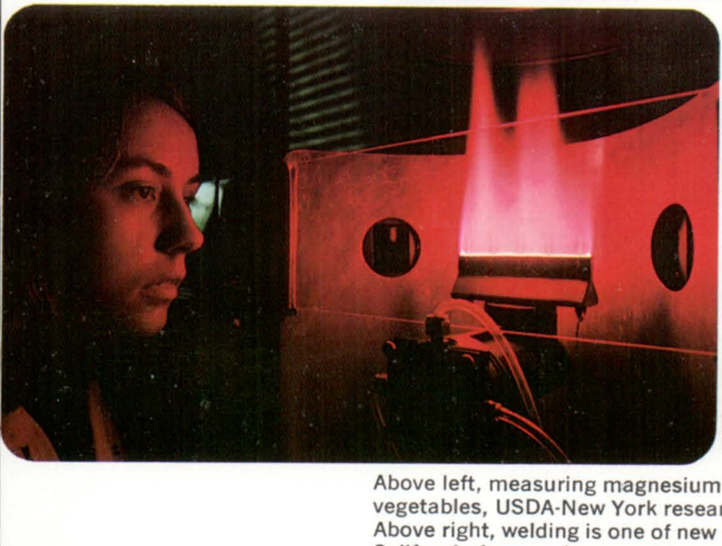
Right, artificial insemination study of broiler-breeder birds, South Carolina. Three center photos, virtually painless freeze-marking technique developed by USDA-Washington research for identifying animals such as horses, ponies, and deer. Bottom, specific-pathogen-free pigs are derived by caesarean surgery on mother sow into a sterile plastic bag, Tennessee.



Left, California researchers experimented by taking calf from mother at an early age and feeding for rapid growth. Below, Iowans get animal ready for National Dairy Cattle Congress.

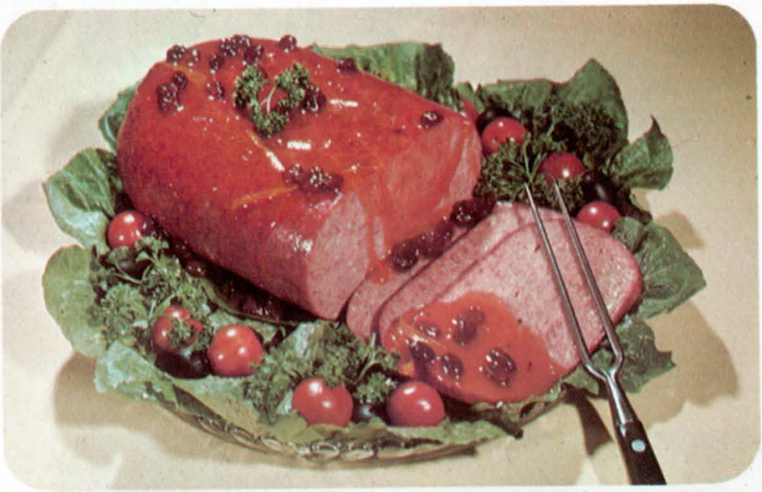
Below, harvesting large plots of cotton in Mississippi comparison of experimental defoliants. Left, toys measure infant development, in Ohio child study.

Top right, studying influence of manganese and boron nutrition on young cotton, Georgia. Top left, irrigating cotton, California.



Above left, measuring magnesium in vegetables, USDA-New York research. Above right, welding is one of new skills California farmworkers are learning through training programs to qualify them for year-round employment in agriculture.

Bottom, lean pork chops are result of modern genetics and animal nutrition. Below, tasty pork roll developed in Nebraska by freezing low priced cuts and scraps of pork, flaking it, then forming flakes into "logs". Left, Texas is studying economic possibilities of freshwater shrimp. Opposite page: Top, three leading catfish farmers, Kansas. Bottom, porterhouse steaks illustrate the best of today's meats—more tender, more nutritious than ever before.

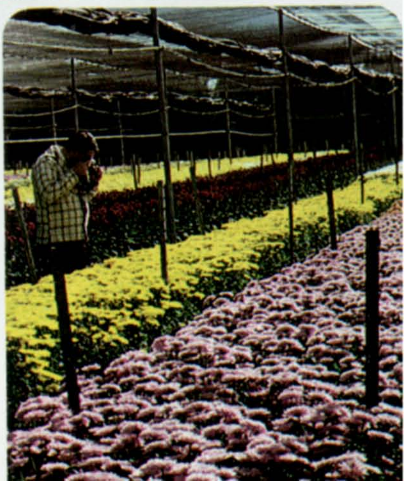


Conservation of energy and the environment are two important goals of State research. Right, Arizona scientists are studying "people carrying" capacities of areas such as the Grand Canyon. Center photos, testing solar energy use to dry grain or other agricultural commodities, in Ohio (left) and Iowa. Bottom, many States are seeking new ways for disposing of feedlot wastes without ecological damage.

Big tractor rig prepares land
for fallow in State of Washington.
Good conservation practices
are based on research.

Below, high degree of color uniformity of flowering plants obtained through asexual tissue culture in California. Photo at far left shows varied colors of plants obtained from seedlings. Uniformity is important for flower industry. Left, popular zebra plant is demanding in its requirements, thus is subject of much research in Florida, where about half of all foliage plants in U.S. homes have their origin.

Above, new mountain laurel selection with red buds and banded flowers, developed in Connecticut. Right, 20 years of research stand behind success of Florida's winter chrysanthemum industry.



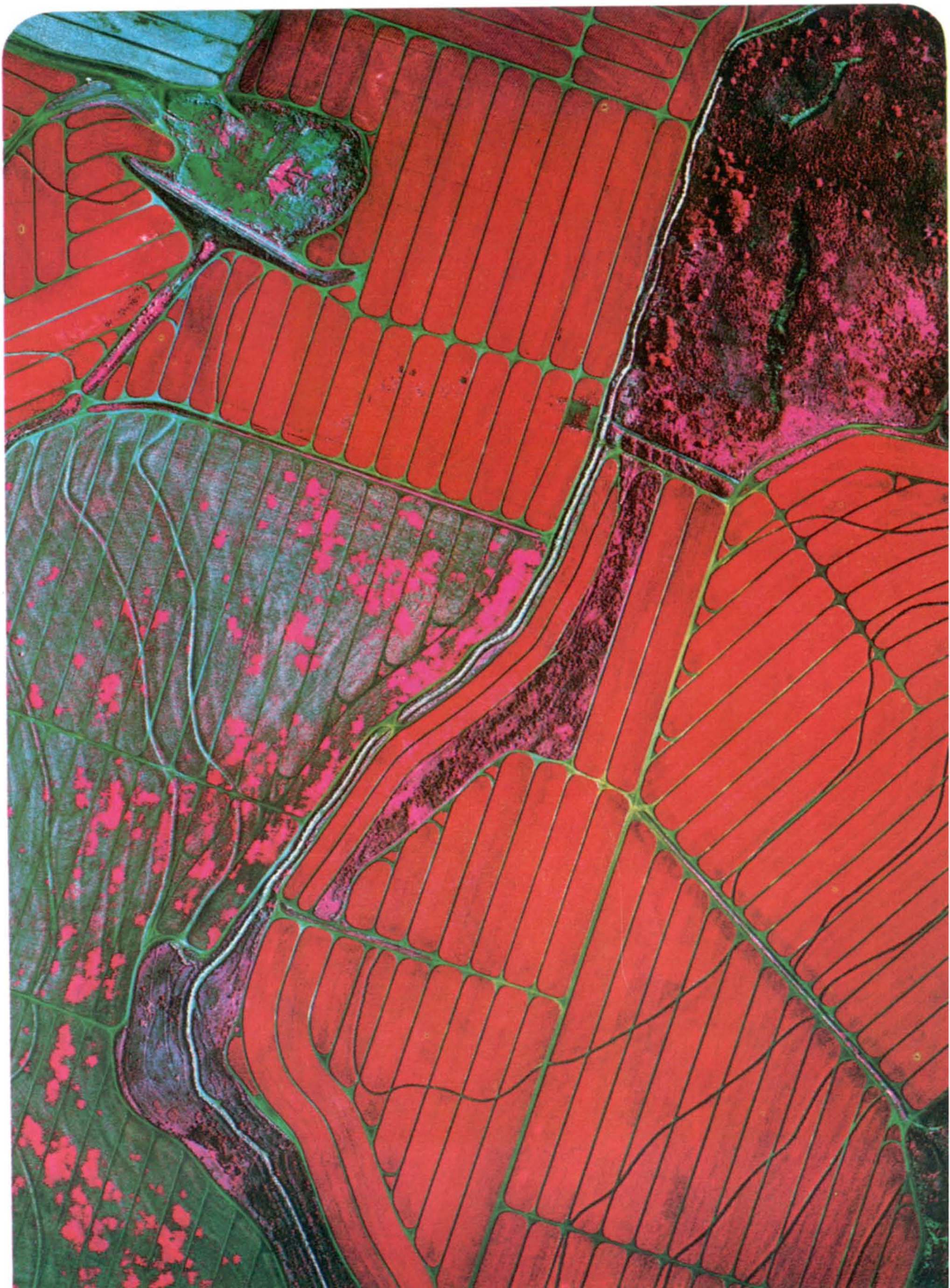
Above, checking height of flower and size of bloom, key measures of snapdragon variety desirability, Alabama. Left, modern long lasting poinsettias grow in Florida.

Bottom, mosquito gorged with blood, and enlargement of a skeeter's business end, California. Right, mosquito-fish that eats mosquito larvae. California is working on mass culture techniques for the mosquitofish. Below, California researcher sets light trap in evening to sample mosquito population.

Below, early warning system based on a chemical repellant (alarm pheromone) was discovered in aphids by scientists from Ohio, New York, and Massachusetts. When a predator insect attacks, the aphid secretes a droplet of pheromone which warns other aphids. Possibility of treating plants with synthetic pheromones to scare aphids away is being explored.

Top of page, in biological control research conducted with USDA against insect pests, a parasitic wasp attacks a pink bollworm larva in Arizona. Below, parasitic wasp that preys on the Mediterranean fruit fly, Florida.

Aerial color infrared photography is being used in Hawaii-USDA research to detect wild bitter melon infestations, indicated by pink areas in abandoned pineapple field at left (solid red areas are cultivated pineapple fields). This weed is a primary host of the melon fly, a serious pest of melon crops in the Pacific islands. Small photo is a melon fly.



Foreword

EARL L. BUTZ

Secretary of Agriculture

A billion-dollar saving through just one piece of agricultural research!

That's an estimate of the worldwide economic value of a vaccine to protect poultry against Newcastle Disease. The vaccine was developed at the Virginia Agricultural Experiment Station.

This is just one striking example of what the State Experiment Stations are doing. There are many other dramatic examples that you can read about in this 1975 Yearbook of Agriculture, *That We May Eat*. Among them is the monumental discovery of vitamins.

You are directly helped in many ways by agricultural research. The experiment stations had a big hand in developing today's meaty, tasty, economical chicken. Their research made possible the fried chicken that you eat at neighborhood fast-food establishments. In the first years after World War II, it took about four pounds of feed to grow one pound of chicken. Now, two pounds of feed make one pound of chicken. It used to take 14 to 18 weeks for poultrymen to produce a chicken weighing four pounds. Today they raise a four-pounder in less than nine weeks. Scientists have also redesigned the chicken to have more of the meaty portions that you like to eat.

Potatoes are another productive miracle. Connecticut, where the first State Experiment Stations started 100 years ago, grows as many bushels of potatoes now as in 1875, but this takes only a fourth as much land.

One of the book's authors sums up other things the experiment stations have done: They created hybrid corn which increased yields tremendously. They controlled hog cholera which used to destroy millions of pounds of pork each year. They curbed the wheat rust epidemics that threatened to wipe out wheat—and bread. They devised new ways to irrigate dry parts of the country so that we could have larger, more economical supplies of food and fibers.

Experiment station scientists discovered the minor elements of zinc, copper, cobalt, and molybdenum in plant and animal nutrition—and why they are important. Scientists are busy in a never-ending battle protecting plants from enemies such as weeds, fungi, viruses, and insects. Agricultural scientists even discovered dicumarol to control blood clots in humans, streptomycin to treat TB and other diseases, and they discovered the significance of amino acids in your diets.

Scientists also played a star role in stopping the corn blight of 1970—the most destructive disease ever to hit corn. It killed off 15 percent of our huge corn crop that year. In reality, scientists had to go back and correct an earlier mistake they had made—one which made corn susceptible to the blight.

It is said that in the 100 years of the State Experiment Stations, American agriculture has advanced more than in all the millenniums since man first scratched the ground with a stick.

U.S. agricultural achievements are rooted in agricultural research that stems from the very beginnings of the Nation. The first settlers found they had to experiment and adapt, or die. Early chapters in this Yearbook tell about research from Jamestown, Virginia, in the early 17th Century to work by Thomas Jefferson, which shaped our present experiment stations.

I have observed first-hand the work of today's researchers from my years at Purdue University in Indiana where I was Dean of Agriculture. I know, too, of the great cooperation by the people at State Experiment Stations with the people in the U.S. Department of Agriculture (USDA).

Cooperative State-Federal research in agriculture and forestry has consistently discovered new knowledge enabling agriculture, and the Nation, to move forward. Since 1888 Congress has appropriated money for agricultural research, with States matching the money. The Federal funds are administered by USDA's Cooperative State Research Service to do research ranging from environmental quality to improving beef cattle. The Agricultural Research Service in USDA also participates in these programs through cooperative agreements with the States for research work.

No attempt has been made in this book to include stories of achievements from all of our Stations. We are only describing *some* highlights of State Experiment Station research that we thought would be fascinating to you. The miracles are so commonplace we can't report them all!

Preface

Jack Hayes

Yearbook Editor

That We May Eat, the 1975 Yearbook of Agriculture, should appeal to just about all Americans, but especially to adults and to youth of high school and college age.

The Yearbook marks the 1975 centennial of the State Agricultural Experiment Stations by reporting experiment station successes which have brought us a better life. This 100th year celebration is a warmup to America's 1976 Bicentennial.

Authors have sought to write sparkling accounts as fascinating as research itself, which still have the stature of reference pieces. There is a wealth of photos.

This Yearbook describes past achievements of the experiment stations that mean a great deal to you in your everyday life, tells of their ongoing research into current problems that affect all of us directly or indirectly, and peers into the future at rocks in the path and surmises how they may be dug out.

State Experiment Station folks asked the U.S. Department of Agriculture (USDA) to do this book, and USDA was happy to comply. A prime mover was Paul Waggoner, Director of the Connecticut Station at New Haven—the Nation's very first Station. Paul has a realistic point of view which might serve well for America's Bicentennial. Let me quote him:

"At the end of the first century of the Stations we can point with pride at their accomplishments. Mostly, however, we see things to do. The union of theory and practice in America's Stations for discovery is a powerful force for improving the human condition. But a century is only a beginning . . ."

Many persons have contributed to this Yearbook, and some are sure to slip by without receiving due credit. The 1975 Yearbook Committee is listed at the end of this Preface. Most members came long distances from their home States to attend meetings.

Participating in early planning sessions for the book and making additional contributions were Claude Gifford, USDA's Director of Communication; and Hal Taylor, Deputy Director.

Yearbook staff members Mary Vest and Denver Browning worked on all phases of the book and collaborated on the Index.

The book was published by the Government Printing Office (GPO).

James Watson of GPO's Typography and Design Division was the book's typographer. Other contributors from that Division include Howard Behrens who laid out the color pages, and Linda Sherman, the cover designer. Production coordinator was Paul Wertz, USDA's Office of Communication.

Editorial Note: To avoid endless repetition of such words as "State Agricultural Experiment Station" in photo captions, the name of the State involved alone is given as a rule. (A list of the Stations begins on Page 351.)

ROY LOVVORN, Administrator of USDA's Cooperative State Research Service, was chairman of the Yearbook Committee that planned the book.

Yearbook Committee members were:

JAMES ANDERSON, Mississippi Agricultural and Forestry Experiment Station

TONY CUNHA, University of Florida

GLEN GOSS, Pennsylvania State University

JAMES HALPIN, Director-at-Large, Southern Agricultural Experiment Station Directors

JAMES KENDRICK, University of California, Agricultural Experiment Station

LEE KOLMER, Iowa Agricultural and Home Economics Experiment Station

WARD KONKLE, Cooperative State Research Service (retired)

ROY KOTTMAN, Ohio Agricultural Research and Development Center

JARVIS MILLER, Texas A&M University, Agricultural Experiment Station

WAYNE RASMUSSEN, Economic Research Service, USDA

ROBERT RATHBONE, Agricultural Research Service, USDA

DONALD ROBERTSON, Office of Audit, USDA

PAUL WAGGONER, Connecticut Agricultural Experiment Station

SYLVAN WITTWER, Michigan State University, Agricultural Experiment Station

Contents

BEGINNINGS

The First Two Stations—Connecticut, California

By Paul E. Waggoner and Paul Gough

By coincidence, two scientists who grew up in the United States, had boyhood laboratories, and were educated in Germany, built experiment stations on both of the American coasts.

The scientific achievements of State Agricultural Experiment Stations such as hybrid corn, antibiotics (for example, Streptomycin and Aureomycin), and the discovery of vitamins didn't just happen. They came from scientific institutions set up as the result of a dream, peddled from buggies to farmers' meetings and State legislatures.

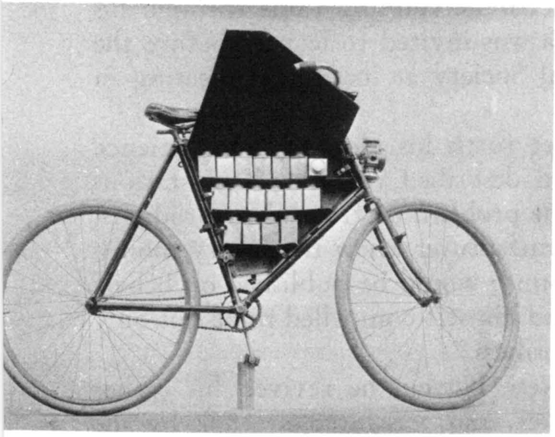
Before the mid 1870's when the first experiment station was founded in Yankee Connecticut, there were many farmers, but few had the knowledge, inclination or ability to conduct experiments, based on scientific knowledge, to improve the state of agriculture. Schools had to teach what the best farmers did, not what science revealed.

Realizing that science could serve agriculture, a small core of concerned men—including Connecticut's Samuel W. Johnson and California's Eugene W. Hilgard—worked to establish Agricultural Experiment Stations modeled after those in Germany.

Johnson was the son of a New York farmer who felt the only way other than farming in which a young man could make a decent living in those days was to be a doctor or a lawyer. Fortunately for farmers and the people who depend upon them for food, the elder Johnson was wrong.

Johnson the scientist was a bookish young man. He was driven by an interest in natural science and a desire to put science to work for society. Some of his first scientific experi-

Paul E. Waggoner is Director, The Connecticut Agricultural Experiment Station, New Haven. Paul Gough is Editor at the Station.



Left, bicycle used for collecting feed samples in early 20th Century, to protect Connecticut farmers from fraud. Above, Virgil Churchill on sampling bike.

ments were conducted in a small laboratory at the family farm when he was 18 years old.

After graduation from Lowville Academy, Johnson taught general school subjects for several years before becoming an instructor in science at the Flushing Institute on Long Island, and at the State Normal School in Albany.

In 1850, he entered the Yale Scientific School to study agricultural chemistry. As was necessary in those days to succeed in science, Johnson studied for two years in Germany, supported financially by his father. There he saw the German Station at Moeckern, which was the first of its kind. The German name for this institute was literally "Agricultural Experiment Station."

Johnson, who often wrote for *The Cultivator* and *The Country Gentleman,* described the work of the experiment station in an article, and years later was to travel around like a politician seeking votes as he campaigned for a similar experiment station in the New World. One can imagine the railroads and buggies he rode and the meeting houses where he spoke in preaching the union of theory and practice.

During the fall of 1855, Johnson returned to New Haven to become chief assistant at the Yale Scientific School chemical laboratory. In 1856 he was appointed to the chair in agricultural chemistry.

Fraud and Fertilizer

Johnson helped to build support for an experiment station by offering farmers information they could use on the composition of fertilizer, based on analysis rather than the all-too-frequently fraudulent claims of manufacturers. Gaining fame through his writing and speeches, Johnson was invited to lecture before the New York State Agricultural Society at its annual meeting in February 1856.

In that lecture, Johnson set forth his ideas on what science could do for agriculture, and described the European stations and their work. To combat the problem of fraudulent products, Johnson suggested "if the manufacturer knew that every month or so a new analysis of his manure would be published on behalf of the farmer . . . he would find himself compelled to be not only honest, but careful in his business."

As Johnson returned to New Haven, he revived his earlier practice of evaluating fertilizer, and was hired in 1857 by the Connecticut Agricultural Society to perform such analyses and to issue reports for farmers.

Johnson issued three annual reports, but the outbreak of the Civil War in 1861 led to the demise of the Agricultural Society. After Appomattox, the State Board of Agriculture was set up, and Johnson was appointed its chemist, holding that position until 1898.

After returning from the February 1872 convention of agricultural colleges in Washington, Johnson renewed his campaign for an experiment station. At a Board of Agriculture meeting in December 1873, Johnson and W. H. Brewer of Yale discussed German Experiment Stations and his protege, Wilbur O. Atwater, spoke on commercial fertilizers.

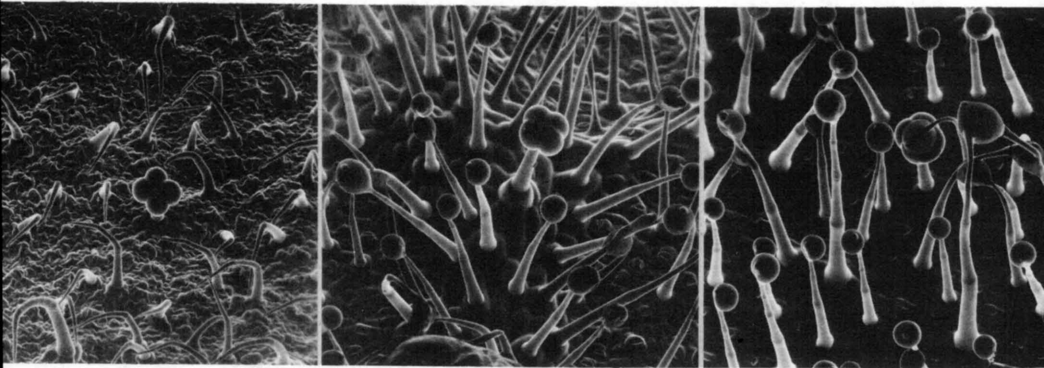
Later, as chairman of a committee appointed at this meeting, Johnson, not surprisingly, reported the unanimous opinion of its members was that "the state of Connecticut ought to have an Experiment Station as good as can be found anywhere, and they are of the opinion that the legislature of the state ought to furnish the means."

Stumping for a Station

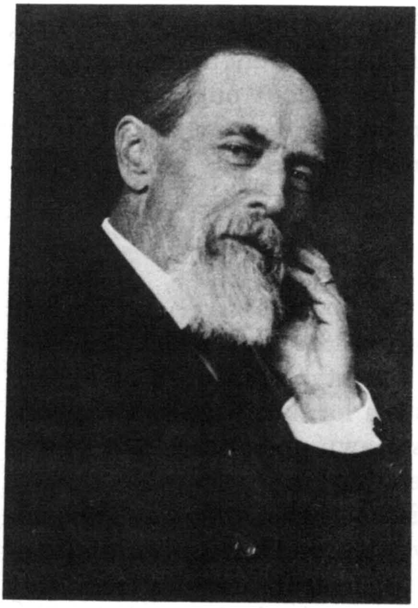
This report was adopted, and the Board of Agriculture held 17 meetings in different parts of the State at which Johnson, Atwater, and others stumped for the establishment of an experiment station. Seventeen meetings is a lot, but happily Connecticut is not a large State. A bill was drawn up for the 1874 legislature; the Agricultural Committee tabled it.

After this, Orange Judd, publisher of the *American Agriculturalist,* trustee of Wesleyan University, and a classmate of Johnson at Yale, offered the Board of Agriculture use of a laboratory at Wesleyan, the services of Atwater, who had been appointed chemist at the university, and $1,000 to start a station.

The following year, the legislature accepted this offer and on July 20, 1875, appropriated $2,800 to the trustees of Wesleyan University "to be used in employing competent scientific men to carry on the appropriate work of an Agricultural Experiment Station" for two years.



Taken with a scanning electron microscope, these photos show hairs on leaf of a tomato and a close relative, *Solanum pennellii.* Tomato leaf at left is susceptible to greenhouse whitefly, while Solanum on right with its glandular hair is resistant to whitefly. By grafting one plant upon the other, a modern-day Connecticut scientist obtained plant in middle, which has core of tomato tissue and skin of the Solanum. New plant is resistant to whiteflies.



Hilgard of California, left, and Johnson of Connecticut.

The station started its work on October 1, 1875, but before the initial appropriation had run out, the legislature passed a new law, moving the experiment station to New Haven, and establishing a Board of Control, which appointed Johnson to serve as director of the station.

Philadelphia Garret

Johnson's boyhood chemistry laboratory was behind the barn in New York, but the boyhood geological laboratory of the California founding father was in a Philadelphia garret where he spent his 16th winter as he prepared to go to Germany for his education in science.

The Bavarian-born Hilgard was the son of a German lawyer who moved his family to Belleville, Ill., when Hilgard was only three years old.

After attending the public schools, and working on his father's farm, Hilgard left the Mark Twain and malaria country along the Mississippi to learn chemistry and geology abroad. On his way, Hilgard stopped by the Smithsonian Institution and met the distinguished Joseph Henry.

After receiving his Doctor of Philosophy at the University of Heidelberg, the boy from Belleville spent the winter in arid Andalusia. Studying the botany and rocks of the countryside,

writing his dissertation, and meeting his wife-to-be, Hilgard became familiar with the Mediterranean-like climate he was to encounter later in California.

Upon his return to the United States, Hilgard accepted a position as chemist of the Smithsonian Institution. But he soon resigned after being summoned to Connecticut for a job interview with a touring professor of physics from the South. Hired as director of the geologic survey of Mississippi after an interview in the State where the first experiment station was to be established, Hilgard surveyed soil and plants, and "served his noviciate in dealing with legislatures." Meanwhile Johnson was analyzing fertilizers and learning to deal with the Yankee farmers who wrote Connecticut's laws.

Although Hilgard's Mississippi Survey was suspended during the Civil War, the State showed its esteem by continuing his salary, and charging him with the preservation of "Ole Miss" during the War.

Attending the first national convention of agricultural colleges in 1871, Hilgard urged a compromise between the academic pursuits of Yale and the trade school approach of Michigan and

"Rainulator" controls amount of water applied to tillage plants, in Illinois tests seeking tillage method that best controls erosion and still gives high yields. This is an example of present-day work at State Agricultural Experiment Stations.

Pennsylvania. He went to the University of Michigan in 1872.

Hilgard went to Connecticut in 1874, again for a job interview, this time with a Californian. His scientific talents were sought because he was a professor who knew legislatures. Because California was a long way off, Hilgard went for a six-month trial, only to find that the man who had hired him had moved east. But Hilgard stayed for the rest of his life.

When he arrived at the University of California in early 1875, Hilgard came to an institution that offered instruction in agriculture but lacked land, facilities, and proper direction. He opened an experimental chemical laboratory and began a field experiment on deep and shallow plowing for wheat grown for hay.

The founding of The Connecticut Agricultural Experiment Station and The California Agricultural Experiment Station, within a few months of each other, reflected the different directions a Station could take. The station on the Atlantic immediately went to work analyzing fertilizers in the laboratory, while the station on the Pacific started with field experiments.

Corresponded Over Years

Hilgard and Johnson obviously were friends united in the pursuit of science because they corresponded over the years.

One letter, written in the 1890's by Hilgard to Johnson, good-naturedly pointed out a typographical error that had never been discovered in a book, *How Crops Feed*, that Johnson had published 38 years earlier. Hilgard wrote, "This reminds me of the gold ducat that for a century passed has been offered to any who would discover a mistake in Vega's Logarithmic Tables. Hadn't you better do likewise?"

Hilgard also told his colleague across the continent, "I wish I were able to give you a personal greeting at Boston, but neither my condition of health nor college arrangements will permit. On such occasions, however, one feels like sending one's old friends and contemporaries greetings."

The boy chemists, one from a laboratory behind a New York barn and the other from a laboratory in a Philadelphia garret, lived on opposite sides of America into the first decade of the 20th century. They saw their dream of experiment stations in each of the States accomplished with the aid of Federal funds, and watched them grow into the scientific enterprises that produced the advances to be described in the chapters that follow.

MILESTONES

Experiment or Starve: The Early Settlers

By Wayne D. Rasmussen

Experiment and adapt, or die. During the winter of 1609–10, two-thirds of the settlers in Jamestown, Virginia, the first permanent English settlement in America, died. That winter was remembered as the "starving time." The survivors experimented with Indian corn and Indian farming, produced food, and lived.

In 1621, Edward Winslow of Plymouth Colony wrote: "Our corn did prove well; and, God be praised, we had a good increase of Indian corn, and our barley indifferent good, but our pease not worth the gathering. . . . Our harvest being gotten in, our governors sent four men on fowling, that so we might, after a special manner rejoice together after we had gathered the fruits of our labors."

The Pilgrim settlers in Massachusetts had, under the guidance of a friendly Indian, experimented with Indian corn. In the spring of 1621 they planted 5 acres of English grain and 20 acres of corn, fertilizing the corn by burying fish with the seed. The corn succeeded; the English grain failed.

The new crop and new methods brought the first Thanksgiving. However, continued experimentation with English wheat, barley, and other crops eventually led to their successful cultivation under the soil and climatic conditions of America. This was done mainly by saving and replanting seeds from the few early plants which produced grain. Thus, by trail and error, British crops were acclimated to the New World.

Corn, which insured survival in Jamestown, Plymouth, and many later settlements in America, had been developed by the

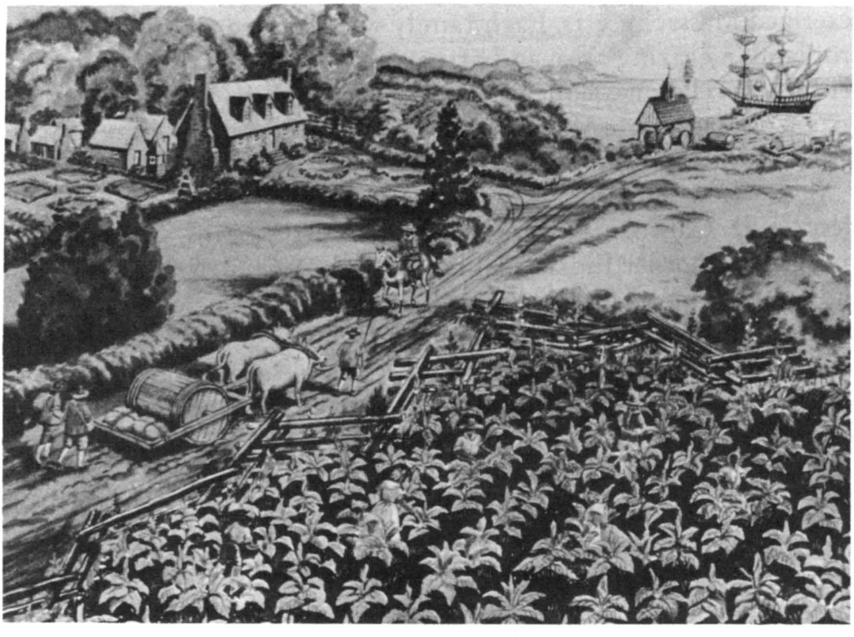
Wayne D. Rasmussen is Program Leader, Agricultural History Group, Economic Research Service, USDA.

American Indians through either amazing chance or a series of experiments which have been impossible to duplicate since. Today corn is America's most valuable single crop.

Indians in what is now the United States also raised avocados, kidney and lima beans, squashes, pumpkins, and probably tomatoes, while those in Central and South America also grew sweet potatoes, white potatoes, peanuts, and other crops. They also grew types of cotton.

One spring day in 1613, John Rolfe—a man with an inquiring mind—stood on a dock in Jamestown, watching as several hogsheads of another Indian crop, tobacco, were loaded on board the ship Elizabeth, bound for England. The variety was not the tobacco first grown in Virginia, but a milder type. Rolfe had secured seed from the West Indies, had planted and cured it in 1612, and was now ready to test the results of his experiment in the market place.

Acceptance was immediate. The large returns from this and following shipments established tobacco as the outstanding cash crop of colonial America. Demands for labor to grow the crop led to the importation of slaves and the development of plantation agriculture in many parts of the South.



Tobacco being rolled to dock for shipment, before Revolution.

Communal Work Fails

Virginia and Plymouth witnessed experiments in economic organization as well as in crop and livestock production. In both colonies, the first settlers were required to work together and to turn everything produced into a common warehouse. The goods thus produced were to be sold for the benefit of the business companies financing the settlements. Until the debts were paid, each settler would receive his subsistence from a common storehouse.

This system of communal work and sharing failed, largely because it penalized workers and rewarded shirkers. The first steps toward abandoning the system in Virginia were taken by Governor Dale in 1611. It was abandoned in Plymouth by Governor Bradford in 1623. In each instance, production showed marked increases when families were assigned their own plots of land and could benefit directly from their efforts.

Efforts to develop new systems of landholding were more successful.

The headright system, with each person coming to the colony given 50 acres of unclaimed land, developed in Virginia and contributed to its growth.

The township system, where groups—usually a religious congregation—would be granted land for establishing a village, characterized Massachusetts. Each family was assigned a building plot, cropland, a grazing area, and often a woodlot, with the village the center of religious, educational, and social life. The township system spread from Massachusetts to Connecticut, New Hampshire, Maine, and Vermont.

Meanwhile, Spanish settlers and explorers in Florida, the Southwest, and California were adopting corn, beans, pumpkins, squashes, and other Indian plants, and were acclimating the grains and other crops of Europe, as well as livestock. Cattle raising and wine making were begun subsequently on the West Coast. However, neither the early grapes nor cattle were particularly productive. Further experimentation, especially in wine making, was necessary in the 19th and 20th centuries.

The first experiment station or plot in the present-day United States was established on the Ashley River in South Carolina in 1669 by the proprietor of the colony. Ships taking settlers to the new colony were directed to stop at the Barbadoes Islands and secure supplies of cotton seed, indigo seed, ginger roots, sugar cane, olive trees and hogs. Two of the settlers were to experiment with these seeds and cuttings; the others were to plant corn,

Pioneer couple, depicted in statuary at Fairmount Park, Philadelphia.

beans, peas, turnips, and sweet potatoes. None of the more exotic crops succeeded well enough to be adopted by the settlers at this time.

Commercial growing of rice began around the turn of the century when, according to tradition, some new seed found in a ship from Madagascar proved to be particularly productive. Earlier experiments with the grain had yielded marginal results.

The Indigo Lady

Indigo production in South Carolina began in the 1740's. Eliza Lucas Pinckney, a young lady left in charge of her father's plantation, experimented with several crops and decided that indigo offered the most opportunity for profit. She was quite successful in her endeavor, although the industry died out when a subsidy offered by the British Government ended with the Revolution.

The second experimental garden and the first public one was established in Savannah, Georgia, in the 1730's by the trustees of the colony, founded as a philanthropic experiment to provide poorer people an opportunity to advance themselves. Even before the garden was established, the trustees hired a botanist to travel in the West Indies and Central America and collect seeds and cuttings for trial. Most of the experiments failed, although the garden distributed grape cuttings and mulberry trees until it was abandoned in the late 1740's.

Meanwhile, in the northern United States, European crops had been acclimated and were being grown in addition to those adopted from the Indians. However, markets were limited because the crops were competitive with those grown in England and northern Europe. Enterprising New England ship captains sought markets in the West Indies, southern Europe, and elsewhere. British interference in trade became a major cause of the American Revolution.

Both new crops and improved varieties were sought. Potatoes, native of South America and introduced into Europe before 1600 by the Spaniards, illustrate the slowness of change. It was not until more than a century after potatoes were taken to Europe that they were brought back across the ocean by Scotch-Irish settlers in New Hampshire.

Some of the colonies at various times attempted to direct their agricultural development, either to become self-sufficient or to open foreign markets, by offering bounties or subsidies or by setting prices. While some of these attempts succeeded for short periods of time, most failed immediately.

In 1640, for example, Connecticut offered to give each farmer, for each team he possessed, 120 acres of land if he would sow a specified number of acres in wheat. The result was a great surplus of wheat and a steep decline in its price.

Then two merchants were given a monopoly in wheat trading in return for agreeing to pay farmers a price fixed by law and to ship the surplus overseas. The plan failed.

In 1640 every Connecticut family was ordered to plant hemp. The law could not be enforced and was subsequently modified to offer a bounty for all hemp grown and linen cloth woven in the colony.

Even though some of the experiments in crop and livestock production and economic organization in colonial America failed, the successes more than offset the failures. By 1775, one hundred years before the opening of the first State Agricultural Experiment Station in Connecticut, thirteen colonies had, through trial and error and planned experimentation, established themselves along the Atlantic seaboard.

Firmly based upon self-sufficient agriculture and trade in the northern colonies and commercial agriculture in the middle and southern colonies, the colonists were upon the verge of revolution against their mother country and were about to begin the greatest experiment in self-government the world had seen.

Jefferson, Washington ... and Other Farmers

By Wayne D. Rasmussen

Land that was seemingly unlimited in extent and available to every European immigrant characterized the original 13 colonies and was the greatest distinguishing factor, in the economic sphere, between the Old World and the New. In the Old World, one was born to the land or never had it. In the New World, one acquired land merely by coming to a new colony or by working a few years until the indenture given for one's passage was paid.

Such was the dream, and the dream came true for most people. When the very existence of the hope and dream seemed to be threatened, the American was willing to fight to preserve it.

The British Proclamation of 1763, forbidding settlement west of the Allegheny Mountains until a future time, antagonized many people. English troops enforced the proclamation by ordering western settlers to return to the east of the mountains. Quitrents, a yearly fee due on all land owned, were found in several colonies and were resented. Entail and primogeniture, restrictions on inheritance, seemed to many Americans to be inappropriate in the New World.

Trade restrictions aroused even more resentment than those on land. Heavy duties were levied from time to time on many colonial agricultural products when they were exported and the more valuable products, such as tobacco and indigo, could be shipped only to England. Restrictions on sales to the French, Dutch and Spanish West Indies limited the markets for colonial wheat and livestock.

Agricultural problems were major causes of the American Revolution, and farms and plantations furnished the leaders, the

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military men, and the food to carry on the war. Notable military leaders such as George Washington of Virginia and Philip Schuyler of New York, backed by governmental leaders such as Thomas Jefferson of Virginia and Henry Laurens of South Carolina, left their farms to win a war and establish a new nation.

With the end of the Revolution, the new nation turned to solving its land problems, bringing new, experimental ideas to old questions.

In the Ordinance of 1785, the Continental Congress established the system of rectangular land surveys, which permitted the exact location of any particular piece of land. Then in the Ordinance of 1787, the nation established the principle that whenever a new area achieved a designated population, it would become a State, equal in every way to the original 13 States. Both of these ordinances, which were experimental and original, encouraged the opening of western lands by American farmers.

Westward Ho

Over the next half-century, westward expansion was of major importance. In 1803 the size of the United States was doubled by the purchase of Louisiana. The Lewis and Clark Expedition into this new area brought knowledge of its plants and animals, as well as of its geography and Indian inhabitants.

In 1845 Texas was annexed, and in 1846 the Oregon Treaty with Great Britain assured the nation of what were to become the States of Washington, Oregon, and Idaho. Two years later, as a result of the Mexican War, the United States acquired the future States of California, Arizona, New Mexico, Nevada, and Utah.

The Revolution stimulated the westward movement and, at the same time, encouraged experimentation and change in farming. Many national leaders, with George Washington and Thomas Jefferson as outstanding examples, urged agricultural improvement and carried on experimental work.

In the words of one of his contemporaries, Washington made Mount Vernon "a veritable experimental farm." He urged crop rotation, replacing tobacco with wheat, clover, and other crops from year to year. Friends in England, including the great agricultural reformer Arthur Young, sent him new seeds and plants. Washington became the nation's first mule breeder, using a jack and jennets sent him by the King of Spain as his basic, experimental stock. He kept careful, comparative records of his ex-

Moving west in 1840's, from Currier & Ives.

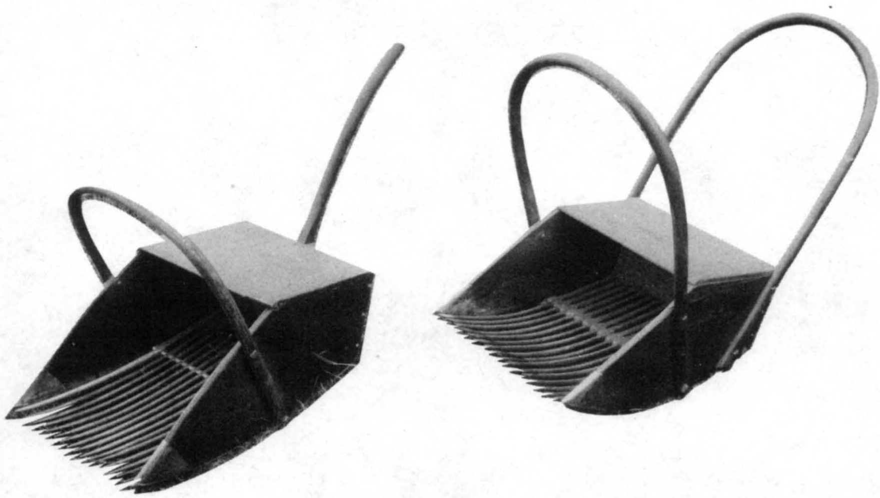
periments with both crops and livestock—at least when the rush of events permitted him to do so.

Thomas Jefferson saw farming as the natural, most rewarding occupation of man, and farmers as the persons most fitted to govern the new nation. He combined an intense interest in improving agriculture through experimentation with his agrarian philosophy. Jefferson encouraged the importation of seeds of improved or new plants, and he himself brought upland rice seed to the United States from Italy.

The need for improvements in the plow attracted Jefferson's attention. He devised a moldboard along scientific principles which would insure that each furrow of soil would be turned. The plan was never put to practical use. However, working with his son-in-law, John Randolph, Jefferson helped design a practical sidehill plow which proved useful.

Both Washington and Jefferson joined with other gentlemen farmers in organizing societies for improving agriculture. The

Cranberry rakes.



first of record was established in New Jersey in 1781. The Philadelphia Society for Promoting Agriculture, organized in 1785, was the first to publish the results of its work. It was followed in the same year by the South Carolina Society for Promoting and Improving Agriculture, by the Society of Maryland for the Encouragement and Improvement of Agriculture in 1786, and by others within a few years.

The early agricultural societies were made up of groups of men of all professions who could afford experimentation and who would seek out and adapt to American conditions the progress made in other countries. They awarded premiums, not for definite itemized products that could be raised by the ordinary farmer, but rather for the best solutions of problems of general significance.

Some of the societies, notably the Philadelphia one, issued regular reports. In 1814, the society published an article by John Lorain on cross-breeding corn, the first step in the long process towards hybridization.

The societies were pioneers in agricultural education and experimentation, even though they had little direct influence upon the ordinary farmers of the time.

One retired banker and businessman, Elkanah Watson of Pittsfield, Mass., believed that local societies, sponsoring annual cattle shows or fairs, would reach local farmers. In 1811 he organized

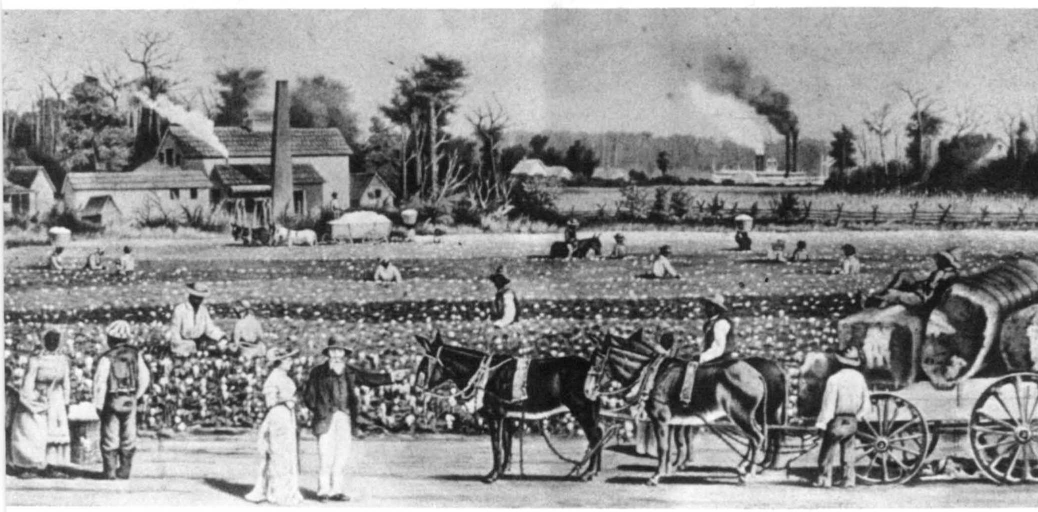
the Berkshire Agricultural Society to sponsor such fairs. The idea spread, and, although they have had problems, county and state fairs still encourage agricultural improvement.

Farm journals reached many farmers and encouraged them to experiment with new crops and improved livestock. The first, the *Agricultural Museum,* began publication in the District of Columbia in 1810, but lasted only a few issues. The *American Farmer,* the first to survive for a long period of time and to attain a nationwide circulation, began in Baltimore in 1819. The editors consistently urged farmers to adopt better methods, and published the results of farm experiments.

A number of farm leaders wrote for farm papers or published their own. Edmund Ruffin of Virginia, the most influential leader of agricultural reform in the South, for example, experimented with marl, essentially a mixture of lime—often in the form of fossil shells—and clay. His report, first printed in the *American Farmer* in 1821, was widely studied and reprinted. In 1833, Ruffin started another journal, the *Farmers' Register*, in which he urged farmers to experiment with new crops and, particularly, with methods to restore the soil.

Yale Man Comes Through

Many articles in the farm press reported on new machines offered to farmers. One machine, the cotton gin, had transformed Southern agriculture before farm journals were estab-



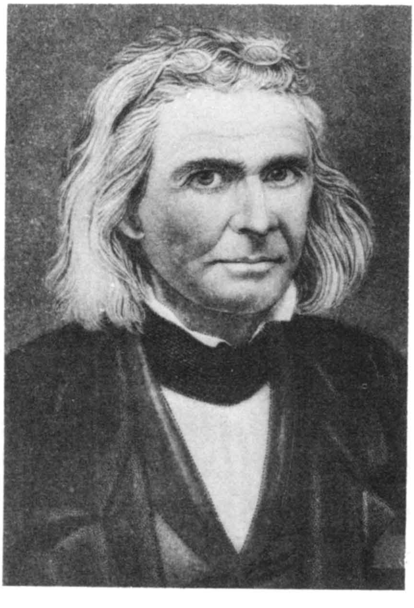
Cotton plantation, 1850, from Currier & Ives.

lished. In 1793 Eli Whitney, a young graduate of Yale University, visited a Georgia plantation on his way to a teaching job. There he learned of the problem of separating the seeds from the fiber of short-staple cotton. Within a few days, Whitney had built a model of a simple, practical machine which did the job.

While Whitney made little money from his patent because the machine was so simple, he changed Southern agriculture. Production of cotton increased from an estimated 10,500 bales in 1793 to 4,486,000 bales in 1861. At the same time, slavery, which had been declining, became profitable. Whitney's experiment had launched the South into commercial agriculture, which was to provide most of the nation's foreign exchange for many decades.

Plows were of key importance. In 1797, Charles Newbold of New Jersey patented a cast-iron plow, but many farmers refused to use it, claiming that the iron poisoned the land and made weeds grow. By 1819, Jethro Wood's improved cast-iron plow with interchangable parts could win acceptance, partly through the educational work of agricultural societies and farm journals.

Neither wood nor cast-iron plows would, however, turn the heavy, sticky soils of the prairies. Steel and high-polished wrought iron shares and moldboards were the answer. Two Illinois black-



Edmund Ruffin, left, urged soil conservation in early 1800's. Cyrus H. McCormick invented practical grain reaper in 1831.

smiths, John Lane and John Deere, experimenting independently in the 1830's, came up with this answer. Deere began manufacturing plows, and by 1857 was turning out 10,000 annually.

The mechanical grain reaper was probably the most significant single invention introduced into farming between 1830 and 1860, doing for northern and western agriculture what the cotton gin had done for the South. The reaper replaced much human power with horse power at the crucial point in grain production when the work must be completed quickly to save a crop. The first machine sufficiently practical to find a market was patented by Obed Hussey in 1833. However, Cyrus H. McCormick of Virginia, who patented his reaper in 1834, became dominant in reaper manufacture.

Many other inventions were patented, some useful and some useless. Among the useful ones were a mowing machine patented in 1844 by William F. Ketchum, and a corn planter which G. W. Brown patented in 1850.

New and improved types of plants and animals were being introduced into the United States. For example, in 1818, Theodorick Bland of Maryland sent club wheat seed to the editor of the *American Farmer* from Chile. The next year, the Secretary of the Treasury sent a circular to consuls and naval officers asking them to send useful seeds and plants back to the United States for experimental use.

Townend Glover of the U. S. Patent Office brought sugar cuttings from South America to Louisiana in 1856. Unfortunately, borers were brought in with the cuttings.

Immigrants, such as Wendelin Grimm, who brought a hardy alfalfa from Germany in 1857, often carried favorite varieties to the United States.

As early as 1783, improved English cattle were imported by Matthew Patton of Virginia and H. D. Gough of Maryland. Henry Clay, the Kentucky statesman, imported Herefords in 1817. Beginning in 1822, John Hare Powel of Pennsylvania built up a well-known herd of Shorthorns.

Many farmers experimented with various materials as fertilizer. Guano, the dried excrement of seafowls, was imported from Peru, and was widely used. The first mixed fertilizers manufactured commercially in the United States were sold in Baltimore in 1849. And the first step towards modern irrigation was taken by the Mormons in Utah in 1847. Earlier, Spanish missionaries had done some irrigating in California.

The first governmental efforts to aid in agricultural improvements were made by the States. Many States appropriated funds to local agricultural societies for aid in holding fairs, but some went further. In 1819 a State board of agriculture was established in New York. It lasted until 1825. While this first experiment was not effective, it was followed by an agricultural survey in Massachusetts. Beginning in 1837, Henry Colman visited all parts of the State and issued four reports, including statistics and recommendations for change. This work was a direct forerunner of present-day State Departments of Agriculture.

Although George Washington had proposed a national board of agriculture, it was not until 1839 that Congress appropriated $1,000 to be used by the Patent Office for "the collection of agricultural statistics, and for other agricultural purposes." It was clear that other purposes included collecting and distributing seeds and plants. However, most of the money appropriated over the next several years was used to print an annual report on agriculture. It was devoted mainly to letters from farmers on experiments and improvements they had undertaken. The idea of a nationwide system of agricultural experiment stations was expressed as early as 1845.

By 1862, a year of major agricultural reform, the foundations had been laid for the first American agricultural revolution.

Lincoln and the Liberation of the Man on the Land

BY WAYNE D. RASMUSSEN

"No other human occupation," wrote Abraham Lincoln in 1859, "opens so wide a field for the profitable and agreeable combination of labor with cultivated thought, as agriculture." In 1862, a year after he had become President, Lincoln signed into law four acts to encourage research and experimentation and to aid the family farmer.

The first of the four laws established an independent Department of Agriculture. The idea for such an agency went back to George Washington, who in 1796 had urged the creation of a national board of agriculture. The Maryland Agricultural Society in 1849, and the United States Agricultural Society later, called for a Department.

In 1861, Thomas G. Clemson of South Carolina outlined a plan of work for a Department, emphasizing the need for agricultural experimentation. The new agency followed Clemson's proposals. The basic legislation was broad, directing the Department, among other duties, to acquire information by "practical and scientific experiments."

The second agricultural reform law, the Homestead Act, gave 160 acres of public land to heads of families or persons over 21 years of age, who would improve the land and live on it for five years.

This law did not achieve all that its proponents hoped. There were many cases of fraudulent entries and the law worked at cross-purposes with other land laws. Most of the public land was in the arid West, where 160 acres was too much land for irrigated farming and too little for dry-land farming or grazing.

Nevertheless, the Homestead Act stood as a symbol of Ameri-

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can democracy to native-born and immigrant alike. And many settlers, particularly those willing to experiment in the new conditions, became successful farmers.

The Homestead Act opened new land. The Transcontinental Railroad Act provided a means for farmers in part of the newly-settled land to get their products to market. The act provided the financing, mainly through land grants, to build the Union Pacific Railroad. Similar grants were made to other railroads later.

The fourth agricultural reform act, the Morrill Land Grant College Act, granted land to each State for colleges of agriculture and the mechanic arts. For more than ten years, Jonathan Turner of Illinois had kept the idea before the American people. State agricultural colleges had been established on a permanent basis in Michigan and Pennsylvania in 1855, in Maryland in 1856, and in Iowa in 1858.

The United States Agricultural Society and many farm journal editors called for national assistance. Beginning in 1857, Justin S. Morrill, representative in Congress from Vermont, introduced bills for this purpose. Finally, in 1862, his proposal became law. Eventually, every State accepted its terms and established one or more colleges of agriculture and engineering.

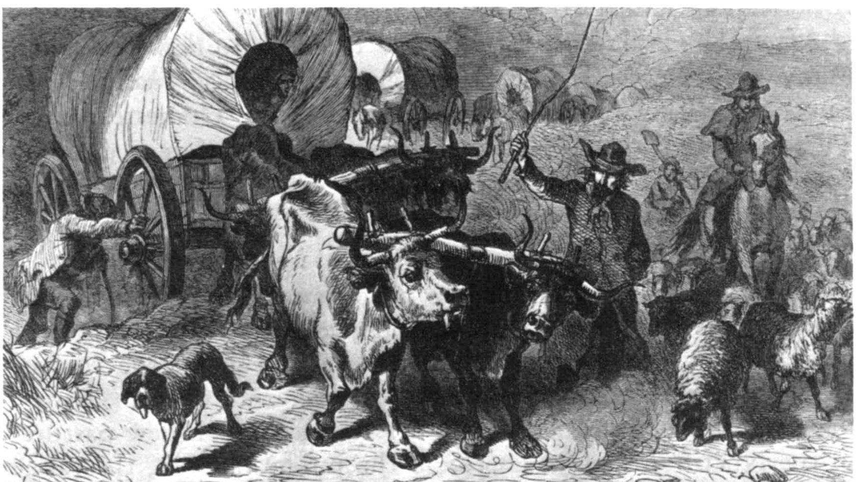
Within a period of three months, President Lincoln had signed laws which provided a broad base for expansion of agricultural research and education and for settling the West. Still missing was provision for a nationwide system for State Experiment Stations and a means for carrying the results of research directly to the farmers. These needs would be met in the future by passage of the Hatch Experiment Station Act in 1887 and the Smith-Lever Act in 1914.

Britain and the Blockade

The new legislation came as the Civil War was pitting section against section. As the war began, the South counted on British needs for cotton to win recognition of the Confederate States and to break the Northern blockade of Southern ports. However, poor harvests in England and some of Europe during the early 1860's led to an increased demand from England for Western wheat. This, and other considerations, outweighed the needs for cotton, and England did not challenge the blockade.

Without a ready market for cotton and cut off from Western and Northern supplies of food, the South turned to subsistence

Above, sod house in Nebraska, 1887. Note sash and glass window, and shaded "patio" at left with table and benches for outdoor dining. Below, emigration to the western country, wood engraving by Bobbett after F. C. Darley.



agriculture during the war. Much experimenting was done in an effort to increase food supplies.

Northern farmers, on the other hand, turned to commercial agriculture. With constantly rising prices, a seemingly unlimited demand for farm products, and the movement of a million farmers and farm workers from agricultural production to the army, the men and women remaining on the farms were willing to experiment with horse-drawn machinery. They turned particularly to the reapers and threshers, because it was in harvesting grain that the labor shortage was most vital.

These machines were quickly followed by horse-drawn plows, grain drills, hay mowers and rakes, and cultivators. They had been invented earlier, but many farmers had hesitated to invest in them so long as sufficient labor was available on the farms to carry out the work by hand and with oxen.

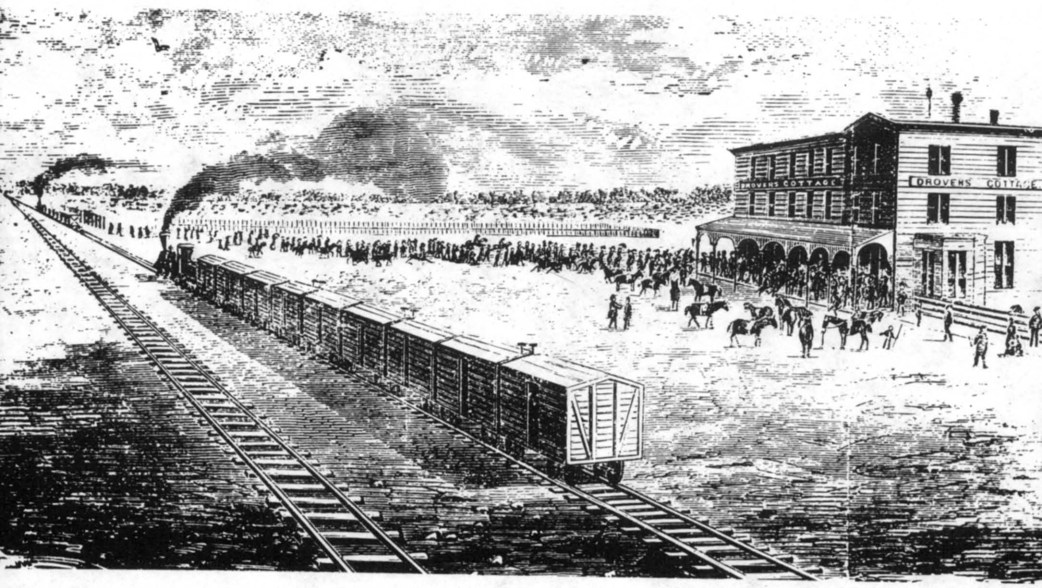
Replacement of human power by animal power, the trend away from self-sufficient to commercial agriculture, the willingness of farmers to experiment with new machines and new practices, and encouragement in these directions given by the new State Colleges of Agriculture and the U.S. Department of Agriculture (USDA), resulted in the first American agricultural revolution.

In the years during and just after the Civil War, farm production and production per farm worker increased at a substantially greater rate than before the war or than during the latter part of the 19th century. Such a relative increase in productivity was not to be seen again until World War II triggered the second American agricultural revolution.

After the Civil War, farmers had to adapt to new situations. Many went West, joining immigrants from virtually every European nation in taking up land under the Homestead Act. These settlers had to adapt to a drier climate, different growing conditions, and changing markets.

Cowboys and Longhorns

Farmers moving West had to accommodate to the livestock economy which, in most areas, had preceded them. After the war, long-horned range cattle had been driven by the tens of thousands north to railheads in Kansas for shipment to eastern markets. Some of the herds were driven on to stock new pastures in the Northern Plains. There, on the public domain, the range cattle industry developed, similar in some ways to the open range



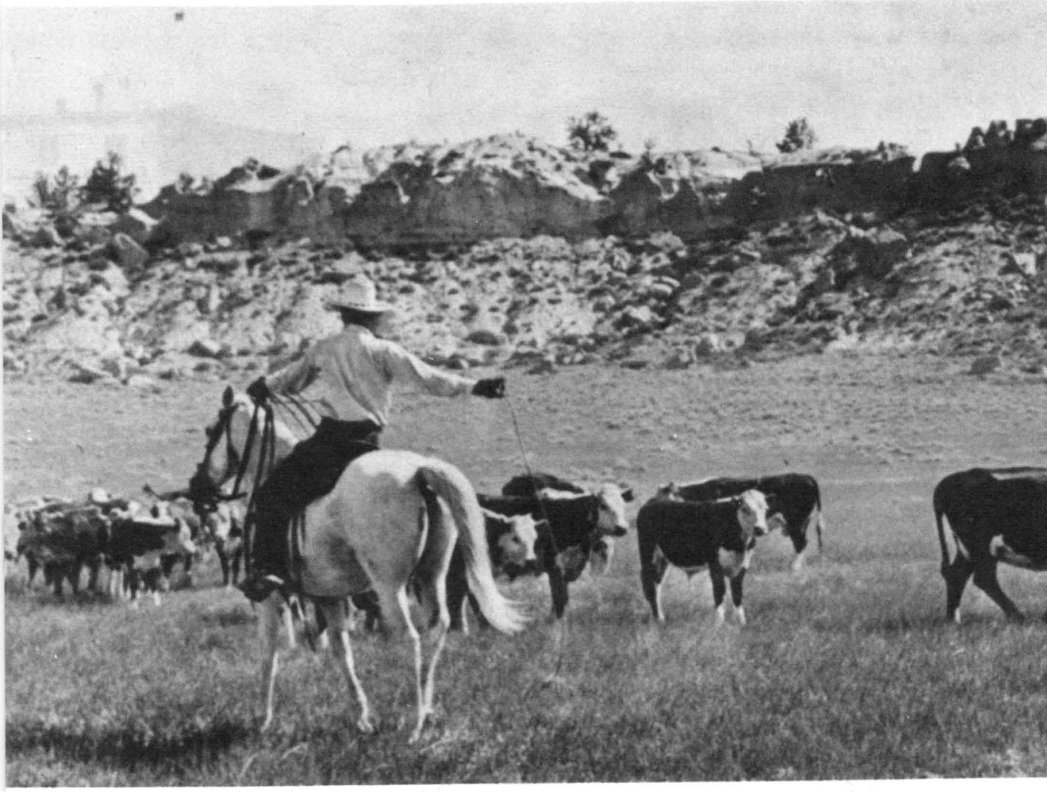
Railhead at Ellsworth, Kans. Trains are leaving for Kansas City loaded with cattle.

of the back-country of colonial Virginia and Carolina. The cowboy, epitomizing the American free spirit and the ability to overcome adversity, became an American folk hero.

For a few years, the open range seemed inexhaustible. But overstocking and the hard winter of 1886–87 brought that era to a close. Ranchers had to turn to controlled range management, to more productive breeds of livestock, to water storage, and to irrigating land and raising hay. This transition was aided by the new State agricultural colleges and, a bit later, the experiment stations.

In the South, cotton dominated farm life. Faced by the problems of Reconstruction, the larger landowners turned to sharecropping as a way of assuring a supply of labor. Often the croppers, the landowners, and the land itself suffered from this emphasis upon a single crop, particularly one grown by methods which brought erosion of the soil.

The new Colleges of Agriculture and experiment stations, as well as USDA, experimented with higher-yielding varieties of cotton and with fertilizer, and urged the planters to practice soil conservation. Some scientists, such as George Washington Carver of Tuskegee Institute, urged diversification. He sought new uses for peanuts so that farmers might have a real alternative to cotton.



Branding calves on Montana ranch.

As the scientists and experiment stations showed the way, change began, but it came slowly.

The East found itself in competition with the West after the war so far as grain and livestock were concerned. As cities continued to grow, more and more farmers turned to dairying and market gardening. These changes brought new problems in both production and marketing.

Establishment of butter and cheese cooperatives in New York and other Eastern States before and after the war was a major effort to deal with marketing problems.

Farmers also needed advice on producing fruits and vegetables for market, and indeed on how to handle the many difficult problems facing Eastern farmers as they tried to keep their farms in operation. This is one reason there was support in the East for establishing experiment stations.

Billion Bushel Corn

Rapid expansion in corn production in the Middle West took place after the war. In 1870, the nation harvested its first billion bushel crop. Many returning Civil War veterans settled on the prairies, using horse-drawn machinery on their new farms. The acreage in corn increased from 44 million to 62 million acres in the five years from 1875 to 1880, and the corn crop per farm doubled in the decade 1869–1879.

By 1879, the Corn Belt was rather well defined, with production centered in Illinois, Iowa, and Missouri, with Kansas and Nebraska developing rapidly. Much of the crop was fed to hogs on farms.

Invention of efficient, horse-drawn machinery had contributed to increased production. Development of new varieties was also important. Some resulted from planned efforts, some seemed ac-

Railroad car that took displays to California farmers showing better varieties and other results of research.

cidental. One famous variety, for example, Reid's Yellow Dent, originated in 1846 when Robert Reid took a late, rather light reddish colored variety from Ohio to Illinois. Because of a poor stand the next year, a small early yellow variety, probably a flint, was used in replanting the missing hills. The resulting mixture was grown by the family, and the new variety eventually came to dominate the Corn Belt. Other purposeful blendings by growers developed varieties well suited to different conditions in the Midwest.

By 1880, the first American agricultural revolution was nearing its end, but it had led to more productive farming throughout the United States. However, farmers had to produce and sell more or turn to different types of farming to stay even as world surpluses and competition from Canada, Argentina, and other new nations depressed prices.

Thus farmers found themselves in the position where they wanted skilled help in increasing production and cutting costs. Such help could come only from experimental work aimed at helping farmers solve practical problems.

It was becoming clearer that a nationwide system of experiment stations was needed to help the farmers continue to contribute to the growth of the national economy.

Research From Soil to Oil: Doing Whatever is Needed

BY ROY L. LOVVORN AND DON V. ROBERTSON

In Pennsylvania in 1895 a group conducted analyses on the relative value of white and yellow varieties of corn. Yellow corn had been thought "richer." The analyses showed that for all practical purposes white and yellow corn are identical, except for color.

In Minnesota in 1974 a group reported a study of the ecology of the Isle Royale moose, with special reference to its habitat. This research was done for the National Park Service, which was concerned about the wide fluctuations, due to die-off, of the moose population on the island.

Both of these research programs were products of State Agricultural Experiment Stations.

The first of the State Agricultural Experiment Stations was established in Connecticut a century ago. Since that time, the work of stations throughout the country has changed considerably, as you can see. But though it has changed, it paradoxically has remained the same.

The work has changed in geographical scope, in research methods, and in subjects investigated. It has remained the same in that it has always been aimed at doing what needed to be done at the time. It always has reflected the needs of the public . . . although the public's needs have changed over the past 100 years.

In the early years the scope of State agricultural research was limited by the boundaries of the State. The annual reports from Maine for the middle 1880's show that the station was engaged in fertilizer testing, varieties testing, and experimenting in composition of cattle foods, digestive processes of cattle, and methods of raising [separating] cream. If you were to read reports from

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Research agronomist with International Plant Protection Center, Oregon State U., evaluates experimental weed control techniques in rice plots at U. of Hawaii.

other eastern stations of the same period—from New York, Pennsylvania, New Hampshire, Connecticut—you would see the same kinds of work being done by each State . . . in isolation.

The times themselves were against cooperation between States. Little money was available to support interaction (the treasurer's report for 1886 from Maine shows a total spent for salaries of $2,985), and the scientists of the day tended to be suspicious of group effort.

But the stations began to realize that individually they could not meet the research needs of American agriculture. Workers, insofar as they were able, began to pool their resources and share information. Then through the years State and Federal governments began to take the legislative steps needed to expand and nurture this cooperation.

In the mid-1940's Congress responded to the leadership of the station directors in Indiana, New York, North Carolina, and Wisconsin by amending the Hatch Act to provide one of the essential requirements for regional research: Funding.

The Committee of Nine then came into being—nine persons elected by, and representing, experiment station directors in their regions. The Committee of Nine advises the U. S. Department

of Agriculture (USDA) on research needs of regional or national significance.

The Office of Experiment Stations, USDA, which had been created for the purpose of administering Hatch funds, became the Cooperative State Research Service—a change that reflected the cooperative endeavors among the States and between State and Federal agencies.

By 1974 even greater emphasis was being placed on regional and national planning, planning that involved not only the State stations but Federal agencies and private organizations as well.

Cooperation by USDA

Many of the research efforts described in this book are results of cooperation between States. An example of the cooperation between the States and Federal agencies is the sharing by USDA's Agricultural Research Service of its research employees with the State stations for cooperative studies of mutual benefit.

The subjects of investigation also have changed over the years. The first work done by the newly established State experiment stations was fertilizer testing. The director of the North Carolina Experiment Station in his report for 1883 stated, "Our work continues to be chiefly that of fertilizer control and that connected with the home production of manures. That is, after all, the subject of the greatest interest and importance to our farming community." He was correct in his statement regarding the interest in fertilizer.

At that time, in the middle 1880's, farmers were being sold many kinds of materials for fertilizers—among them factory sweepings, tannery scrap, and ground crop wastes—with no assurance of their value. The State experiment stations began testing these materials and found that many either were of little value, or were supposedly legitimate fertilizer materials that had been so heavily adulterated their sale as fertilizer materials amounted to little more than fraud.

This protection of the farmers' interest helped win widespread public support for the new experiment station movement.

Fertilizer control soon was transferred to regulatory agencies in the States and the experiment stations went forward to other work, mainly related to farm production. And much of the work now done at the State Agricultural Experiment Stations still is aimed at maintaining, or increasing, farm income by ensuring thrifty production.

The Nevada experiment station, for example, conducts variety trials on grasses for saline soils and conducts irrigation and drainage studies. The Utah station also is concerned with "How to Develop and Use Water—Utah's Life Blood." (*Utah Science*, 1966). And the South Dakota experiment station joins in with studies on trickle irrigation, a method for applying irrigation water that uses up to 20 percent less water than normally is required in sprinkler irrigation. In Vermont, the station has conducted research on the production of balsam fir Christmas trees that has made possible a 40 percent improvement in efficiency of production.

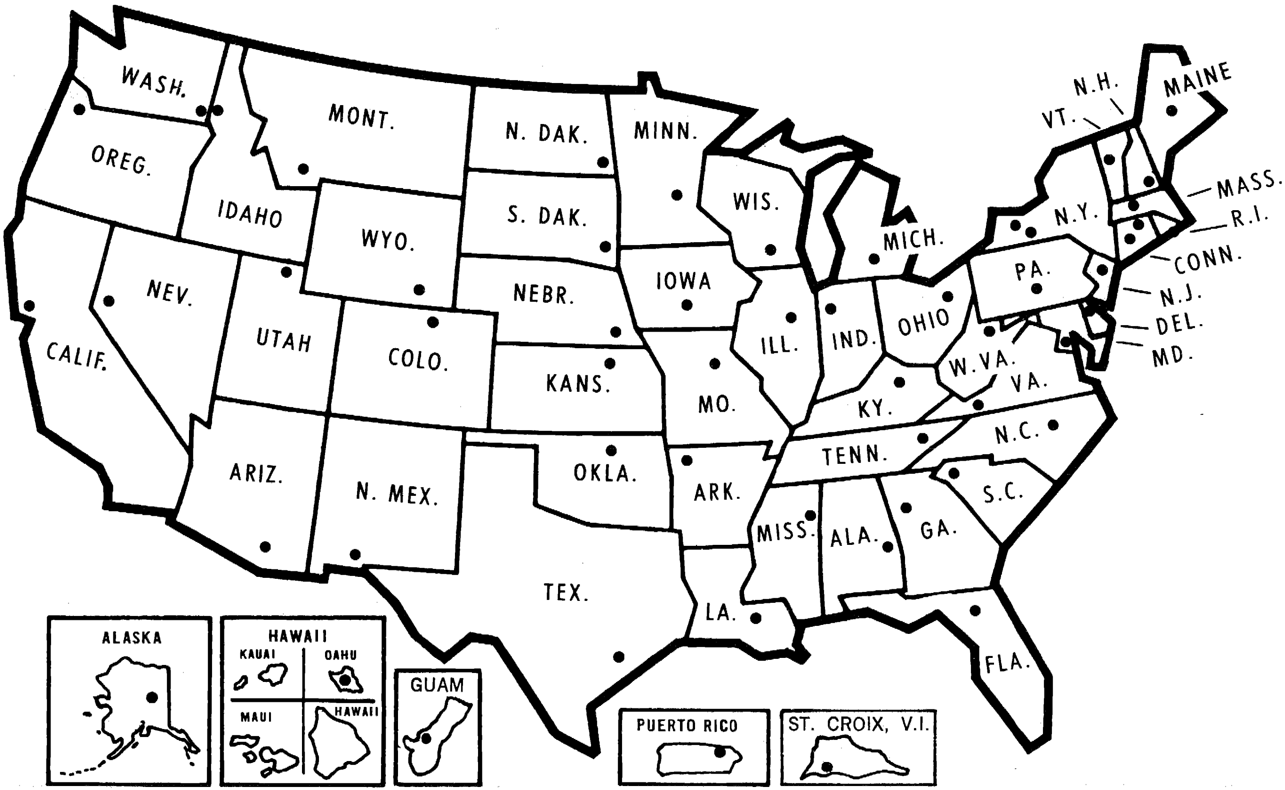
The Nebraska station started animal research more than 75 years ago, concentrating on feeding studies. Its research now includes animal nutrition, physiology, meats, and genetic studies of cattle, hogs, and sheep. Animal scientists at the Texas experiment station are studying reproductive efficiency in angora goats. And in Tennessee the experiment station animal scientists are working on a project for the Atomic Energy Commission studying the biological effects of radiation on domestic animals.

The North Carolina experiment station is using a novel approach to improve the efficiency of hog production. Currently, up to 25 percent of newborn pigs die. The station proposes to cut this death loss by removing the sow from the scene once she gives birth. In her place the station scientists have developed an artificial sow, called *autosow*, a metal carrousel into whose arms the baby pigs are placed immediately after they are born. There the piglets are fed small amounts at frequent intervals to escape their tendency to overwhelm themselves with food; they really *are* pigs, and their overeating can result in diarrhea and death. The scientists also placed the autosow in a controlled environment to escape the common pathogens of pigs.

While much of the research currently done by the State Agricultural Experiment Stations is concerned with production, years ago almost all the research was so directed. In the 1920's some of the emphasis began to shift from the field and barn to the farmhouse and market and town. The stations increased their research into home economics, marketing, and sociology.

Thus the New Hampshire Agricultural Experiment Station has worked on finding ways to conserve the nutritive value of food. At Illinois, economists working on a foreign trade project looked at U.S. agriculture's chances for supplying materials to

● STATE AGRICULTURAL EXPERIMENT STATIONS



the People's Republic of China. And Iowa was concerned with analysis of beef-pork marketing, to determine levels of cattle and hog marketings that could bring the greatest net farm income. Included in the Iowa study was a sophisticated "econometric" model.

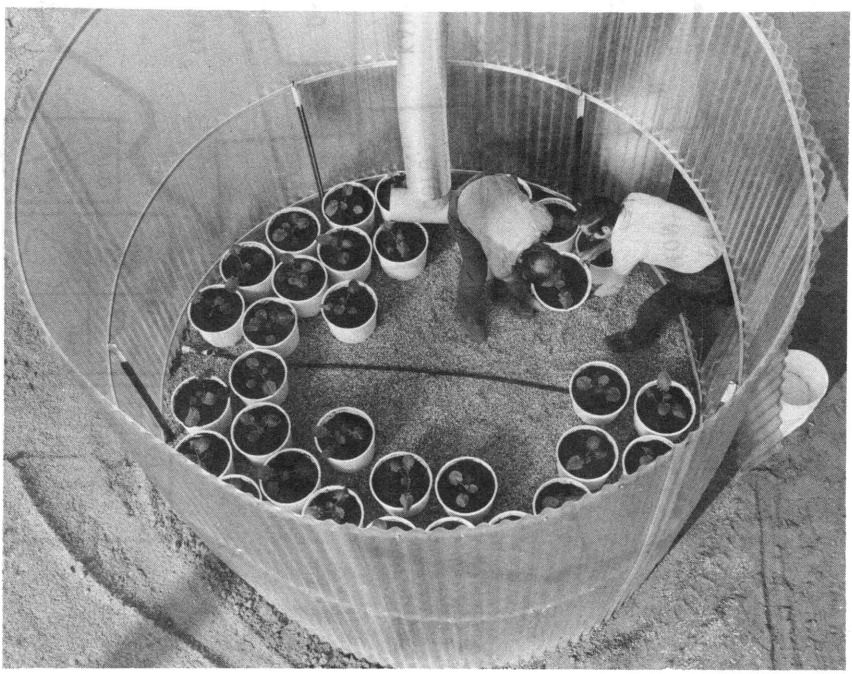
Seafood Studies

Some of the research being done at State Agricultural Experiment Stations scarcely is recognizable as agricultural research—Maryland's studies on commercial fishing and seafood processing industries of the Chesapeake Bay area, for example. This project used experiment station talents for the good of all that State's people.

Another project benefiting all the State was conducted in North Carolina, to stabilize coastal sand dunes.

Nature is in a state of constant change, including the Outer Banks of North Carolina. But roads and homes and towns and livelihoods depend on the coast, and its dunes, remaining much as they are now.

How can the dunes be kept in place? Nature's way is with the roots of plants. So North Carolina agronomists searched for a grass better than Nature's general run of plants. They tested and



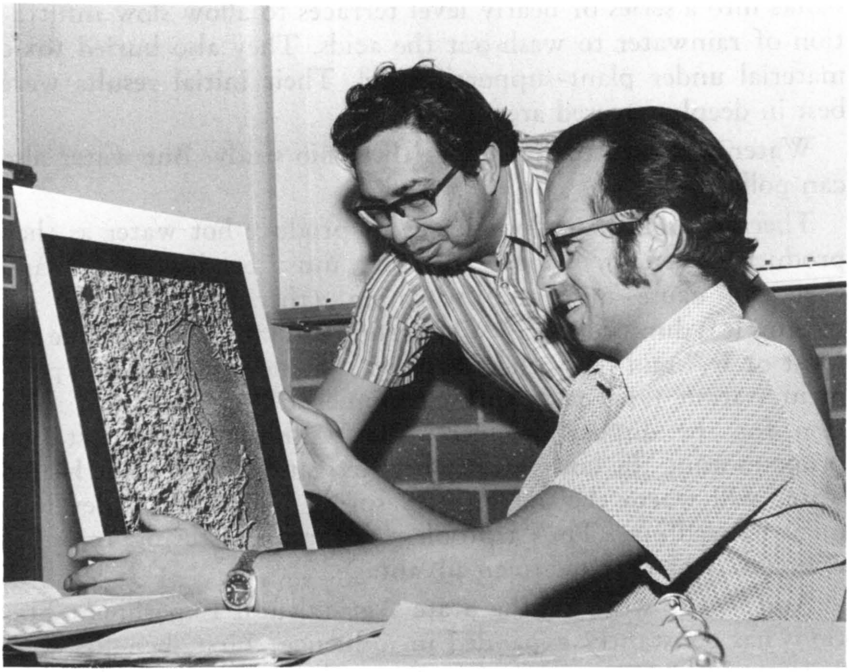
selected and tested again in their search for a superior strain of American beachgrass. Finally they found a variety that seemed to do the job. They named the variety Hatteras, the first named variety of American beachgrass ever developed.

In trials, 70 percent of Hatteras beachgrass survived the first year on the dunes whereas only 5 percent of common American beachgrass survived. And Hatteras trapped more than 5 yards of sand per running foot within 18 months; common American trapped only a trace.

Development of a superior beachgrass does not solve the whole problem of Nature's changeableness, but it is a start.

Like the sand dune project, much of the work of the State experiment stations is now aimed at solving problems that are not exclusively agricultural. In California, for example, the station studied the problem of lead concentrations in plants, soil,

Some California research: Left, plants are put in plastic cylinder to study smog effect on nutrient values of vegetables. Below, Mexico-born scientists examine enlargement of cell wall they synthesized with test tube methods, and photographed through electron microscope. This reportedly is first time a visible cell wall has been synthesized in absence of a living cell or its membranes.



and air near highways—concentrations caused by the antiknock constituent of gasoline.

Pennsylvania tackled the whole problem of environmental disturbances by establishing an office of environmental quality affairs, a clearing house for matters dealing with the environment, particularly those of interest to agriculture and the rural community.

Coal Development

North Dakota studied the effects on agriculture and rural communities of coal development in that State. The researchers said, "Coal development in the Northern Great Plains has a potential to transform the character of the region irrevocably." The study was a beginning, to see what kind of research was needed.

The Ohio experiment station also concerned itself with the effects of coal mining—the past effects—in a study on reclamation of toxic stripmine spoilbanks. Some spoilbanks have remained barren 25 years after mining has stopped. The major factor in the lack of productivity has been acid in the soil from oxidation of sulfur compounds. Investigators graded the spoilbanks into a series of nearly level terraces to allow slow infiltration of rainwater to wash out the acids. They also buried toxic material under plant-supporting soil. Their initial results were best in deeply covered areas.

Water was used to cleanse, in the Ohio study. But water also can pollute.

Thermal and atomic power plants produce hot water as they produce electricity—hot water that must be disposed of and that can cause unwanted warming (thermal pollution) of streams it is dumped into. "When You're in Hot Water, Make the Most of It," said researchers from the Washington State experiment station (*Advance*, spring/summer 1974). In a neat solution for the disposal problem, the Washington State station proposes using the hot water to heat irrigation water. The heated water will warm the soil in early spring to accelerate development of seedlings. Thus a problem adversely affecting an entire region may be changed to an advantage.

And so the work of the State Agricultural Experiment Stations has constantly expanded in influence: First, benefits were restricted to farmers within one State, then made available to the

farmers of an entire region. Now the work of a station commonly is done for the benefit of the country as a whole.

The Alaskan Pipeline

A good illustration of work that benefits the whole country is that carried out in Alaska in relation to the Alaskan oil pipeline, which will carry crude oil from wells on the North Slope across the arctic tundra to the sea.

Many Americans have been apprehensive about construction of this pipeline. They fear damage that the line, and its oil, might do to the wild and precious arctic environment.

Arctic Alaska is a harsh place. Only a thin layer of soil ever thaws during the brief arctic summer. Soil drainage is nonexistent. The only vegetation that can grow there is tundra—grasses, sedges, mosses, and lichens. Under the thin layer of vegetation and wet surface soil the ground is permanently frozen, in some areas to a depth of a thousand feet. This permafrost often contains large deep wedges of solid ice.

But the Arctic, while harsh, also is delicate. If the tundra is damaged, the frozen ground loses its insulation from the sun's rays and begins to thaw. Holes appear in the soil where the surface is scarred. Then gullies, and sometimes caverns, develop as the ice wedges melt.

This fragile environment must endure the stress of heavy construction activity as the Alaskan pipeline is built along an 800-mile path from Prudhoe Bay oilfields to the sea at Valdez. And these activities, no matter how responsibly and carefully controlled, are bound to leave their traces on the surface of the tundra.

Agronomists from the Alaska Institute of Agricultural Science have been working on this problem, searching for plants that can quickly fill in these construction scars. They have been paying particular attention to native plants which already have demonstrated their ability to grow under harsh arctic conditions. They need plants that can grow rapidly in the short arctic growing season, which begins at Prudhoe Bay in mid-June and ceases by the end of August. And when they find suitable plants they must increase the seed stock and release the stock to commercial growers; there are no commercial seed supplies of these plants at present.

But they will find suitable plants, and they will develop management methods for quickly establishing permanent plant

cover. And you and I will benefit every time we go to the gas station.

Science in Agriculture, the periodical of the Pennsylvania station, recently stated, "Since its inception more than a century ago, the College has worked with the contemporary problems of the people." If there is a "big picture" of the State Agricultural Experiment Stations, it is a mosaic picture of work done in response to the people's contemporary need. The chapters that follow all are tiles in this mosaic.

Vitamins Are Discovered by Agricultural Research

BY HUBERT B. VICKERY AND PAUL GOUGH

Vitamins play an important role in our lives. They are necessary for good health and growth, and are an important constituent of the foods we eat.

But, surprisingly, vitamins were a discovery of 20th century agricultural research, not of the medical profession, and were the result of attempts to produce better feed mixtures for domesticated food animals.

It had long been known that certain foods possess the ability to prevent or cure certain diseases, but exactly what it was about the foods which made them work in this manner was still a mystery at the turn of the century.

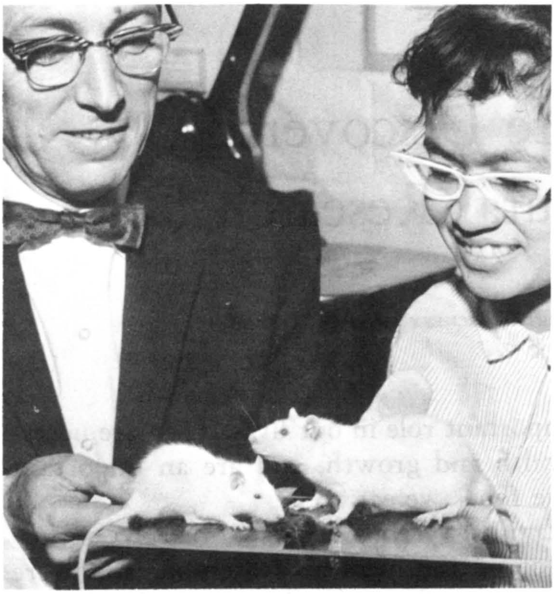
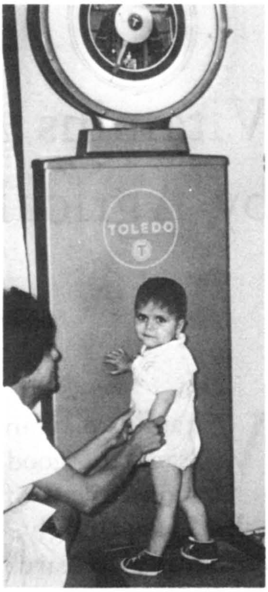
In Wisconsin, research was begun to learn the composition of various foods in hopes of improving the feed for cows and hogs. To do this, the animals were fed varied diets.

Many commonly used rations were found to be deficient in such tests. The record of experiments in the United States and abroad drew attention to properties of milk and whey which seemed to correct such deficiencies.

But, while the problem was clear, it was obvious that experiments with cows and hogs were not going to bring about a quick solution because of the size of the animals and their relatively long lives.

To run such experiments properly, scientists had to isolate the nutrients and to feed carefully measured amounts to animals. Because the available amounts of purified materials were so small, researchers had to turn to other, smaller animals to observe the effects of deficient diets.

Hubert B. Vickery is Samuel W. Johnson Distinguished Scientist and Biochemist Emeritus at The Connecticut Agricultural Experiment Station, and was a colleague of vitamin pioneer Thomas B. Osborne. Paul Gough is Editor at the station.

Left, Edwin T. Mertz displays two rats used in first experimental feeding trial tests with high lysine corn, in Indiana. Right, previously malnourished Colombia youngster weighs in as he approaches normal development thanks to diet largely of high lysine corn.

Despite objections from the administration at the Wisconsin Experiment Station, Elmer V. McCollum started to use rats in his feeding tests in 1907. Imagine the uproar from using the farmer's worst enemy in feeding experiments at a tax-supported research institution!

Fortunately for mankind, such work was allowed to proceed. About two years later, Thomas B. Osborne, a chemist who was the son-in-law of Samuel Johnson, who worked to establish experiment stations and was director at the Connecticut Station, invited Lafayette B. Mendel of Yale to join him in his research at the Station.

The team studied the nutritive properties of proteins Osborne had prepared from the seeds of all of the ordinary crop plants.

In their first experiments, Osborne and Mendel maintained albino rats upon diets made of pure protein, starch, lard, and a salt mixture. Although these rats lived for many months, they ultimately would begin to lose weight and died unless their diet was changed to include whole milk powder.

After further studies, it appeared that the inorganic constituents of milk played an important part in recovery. For

further experiments, Osborne and Mendel removed all of the milk proteins and evaporated the filtered whey to obtain a dry product that contained the sugar lactose and the minerals.

Using this "protein-free milk" as the basic food, the Connecticut scientists were able to maintain rats indefinitely on diets containing a single, purified protein.

They were also able to demonstrate the nutritive inadequacy of certain proteins such as gliadin in wheat or zein in corn. Both are deficient in certain amino acids, the simpler components which make up proteins.

Further work showed that animals fed a protein-deficient diet or a diet low in the amino acid lysine were stunted. However, they began to grow immediately after lysine was added to their diet.

This turned out to be the experiment which showed that certain essential amino acids must be supplied by food because animals have a limited capacity to produce their own.

Although Osborne and Mendel knew they could raise rats to old age on whole milk powder and that protein-free milk helped to maintain rats on artificial diets for long periods, something was missing. That something appeared to be the butter in the whole milk powder diets.

Plot of high lysine corn on Purdue farm.

Vitamin A Discovery

Thus, butter was added to the diets of rats that were declining on protein-free milk diets. Recovery was almost immediate. The Connecticut scientists reported it appeared "as if a substance exerting a marked influence upon growth were present in butter." These words reported the discovery of what would later be called vitamin A.

In the meantime, in Wisconsin, McCollum—working with Marguerite Davis—encountered failures similar to those experienced by Osborne and Mendel in their rat-feeding experiments.

The Wisconsin scientists tried butter and an ether extract of eggs in their artificial diets and made the same discovery as Osborne and Mendel in Connecticut.

Although discovery is the goal of scientists, they must also publish their results so that others may build upon them. McCollum and Davis submitted a report to the *Journal of Biochemistry* exactly three weeks before Osborne and Mendel submitted theirs. Because of this, the Wisconsin scientists are credited with the first report, but it is quite clear that the discoveries were made independently.

The facts learned by experiments of Osborne, Mendel, McCollum and Davis developed within a few years into the vitamin theory of nutrition. Their discoveries led to the conquest of vitamin deficiency diseases such as scurvy, rickets, beri-beri, and others, and also improved the health of the general population.

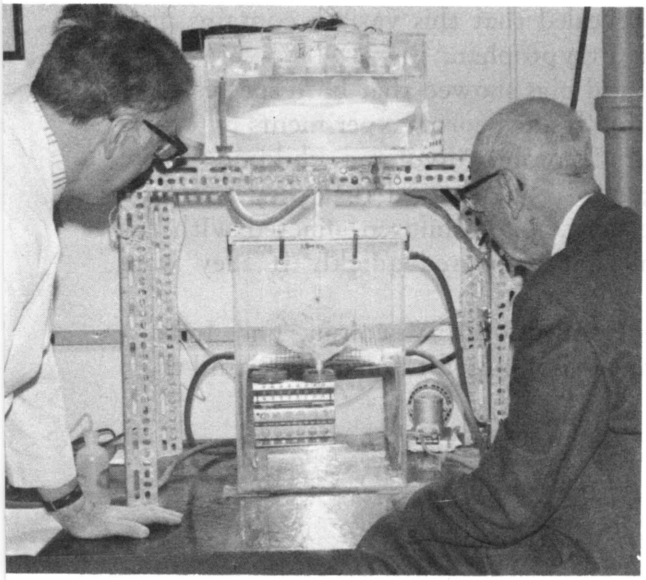
Children's Sight Saved

Further investigations of Osborne and Mendel showed that the unknown factor—later called vitamin A—was present in cod liver oil, a substance long esteemed in medicine. After World War I the eyes of thousands of children in Europe were saved through the use of cod liver oil in their diets.

Osborne and Mendel also showed that chickens could be raised to maturity on an artificial diet which contained the vitamin. This discovery thus laid the foundation for the present-day poultry industry.

In Wisconsin, McCollum and Davis used the curative effect of butter on the vitamin A deficiency-caused eye disease as a test for the vitamin.

Through extensive studies of rice and lactose they were able



Right, girl at work in rat laboratory in Connecticut, probably during 1940's. Left, where Osborne once grew rats to prove essentiality of amino acids and existence of vitamin A, Connecticut scientists now study efficiency of respiration in hopes of increasing the net uptake of photosynthate and thus the yield of crops. Here biochemist Israel Zelitch (left) tells his predecessor, Hubert Vickery, about experiment with a tobacco leaf. Vickery is author of this chapter.

to conclude that there was a second type of essential nutritive factor. The first—vitamin A—was soluble in fat, while the second was soluble in water. The presence of vitamin B as a contaminant in Osborne and Mendel's protein-free milk was undoubtedly why this material was successful in early feeding tests.

Much of our day-to-day awareness of the value of vitamins comes from the nutritional claims for the various food products we see and hear advertised. But in many countries vitamin deficiencies are part of everyday life because children and adults live on a single kind of food.

The lasting scientific value of the work of the scientists in Connecticut and Wisconsin can be illustrated by the work of O. E. Nelson and E. T. Mertz at the Indiana Experiment Station at Purdue.

They became interested in 1963 in the amino acid composition of the proteins of corn. One strain they studied was the so-called opaque-2 which was discovered in Connecticut in 1930.

Analysis of opaque-2 revealed that this variety contains proteins rich in both lysine and tryptophan.

Feeding tests with rats and pigs showed that both species grew much more rapidly on "high lysine" corn. Experiments by others in Central America and Colombia involving children whose normal diets consist largely of corn showed that they benefited greatly from high lysine corn. Also, children afflicted with the deficiency disease kwashiorkor recovered quickly if they were fed high lysine corn.

These experiments in Connecticut, Wisconsin, and Indiana show agricultural research can not only fill stomachs, but fill them with nutritious food.

The Great Depression: Farm Ills Hit the Cities

By Gladys L. Baker and William G. Murray

Five cent cotton and dust darkening the sky. Roads in Oklahoma and Texas filled with jalopies moving to the promised land of the west. And in the cities, bread lines stretching for blocks.

Farming was sick with a disease which spread to the cities. As a writer of the 1930's put it:

> In the fact that farmers were less and less able to buy the things that the people in the cities were making, lies the explanation of how one surplus caused another, until farmers were burning wheat while bread lines lengthened in the cities, until the fantastic spectacle of poverty in the midst of plenty traversed America like a dance of death.

The city workers who were on the street because of the farmers' shrinking purchasing power were not the only ones to suffer as a result of the critical crisis in agriculture. The inability of farmers to pay their debts jeopardized the life savings of other Americans who had invested funds in banks and insurance companies.

An alarming number of farm foreclosures were followed by large numbers of bank failures. In 1931, a total of 1,075 banks failed in towns of less than 5,000 population. After the March 1933 moratorium on all banks imposed by President Roosevelt was lifted, more than 4,000 banks were unable to obtain licenses to reopen their doors. Most of the banks too weak to get licenses were country banks.

Business in rural towns was practically at a standstill. Two

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thousand rural schools failed to open in 1933 because tax delinquency had curtailed county funds.

Widespread droughts in 1933 and 1934 brought the blinding dust of the plains to Washington, D. C. Farmers were losing their livelihood and the Nation was losing its heritage. Congress acted in 1935 with legislation to control soil erosion.

Two years earlier, Congress had acted with unprecedented speed to stimulate recovery in all sectors of the economy. The Agricultural Adjustment Act of 1933 was the first law passed to assist agriculture. Its objective was to raise farmers' purchasing power by controlling agricultural production. Many suggestions were made to the U. S. Department of Agriculture (USDA) on carrying out the law.

Boll Weevil Corps

One correspondent suggested that President Roosevelt set up a "Boll Weevil Corps" similar to the Civilian Conservation Corps which could be used to replace the cotton reduction program of the Agricultural Adjustment Administration. The suggestion, while primarily intended to satirize the New Deal farm programs, also carried an implicit criticism of the scientific research programs. Some farmers and members of Congress were charging that scientific research had caused the surplus production, which in turn caused the depression.

It is not surprising that farmers became critical of the use of government funds for science during the depression. Farmers were in desperate plight because of the severity of the depression which first struck agriculture in 1920. Farm income, which reached $14.5 billion in 1919, dropped to $8.1 billion in 1921, and fell to a tragic low of $4.7 billion in 1932.

Farmers were caught in a squeeze between low farm prices and high farm costs because the depression which struck agriculture did not hit the rest of the economy until the stock market collapsed in 1929. As a result of the big drop in farm prices and the comparatively small decline in farm costs, the average farmer after paying the expenses of production, interest, rent, and taxes had only about $230 left.

Farmers in a number of States turned to direct action, blocking roads and threatening judges and other officials. The State of Iowa enacted a mortgage moratorium law which declared that the safety and welfare of the State as a whole were endangered.

The Governor of Minnesota had forbidden farm mortgage foreclosures and had offered to declare an embargo on the shipment of all farm produce and to enforce it with the State militia if the Governors of neighboring States would join with him.

Noose for Judge's Neck

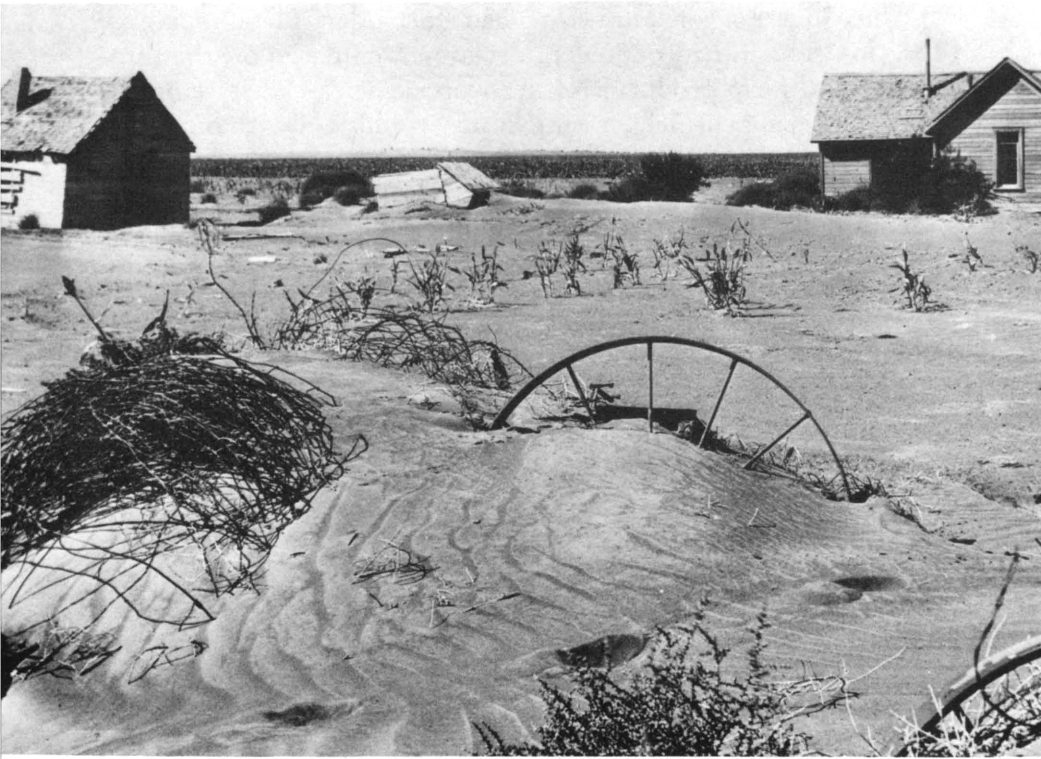
Bands of farmers attended foreclosure sales, bid for items at a penny, and returned them to owners. Angry farmers in western Iowa held a noose around the neck of a judge who had signed a foreclosure order.

Farmers demanded drastic action, not research to improve technology. The criticisms and the need for change to meet depression problems were discussed during the 1931 and 1932 meetings of the land-grant colleges.

In 1931 C. B. Hutchinson, Dean of the College of Agriculture, and Director of the Agricultural Experiment Station of the University of California, discussed "The Influence of Agricultural Research on Our Social and Economic Order."

He divided agricultural research into natural science and social science research, and said that attention had been focused on natural science research. It had been concerned with increasing production and improving the quality of products.

National Guard holds protesting crowd in check at Iowa farm foreclosure sale.



Abandoned Oklahoma farmland, showing the disastrous effects of wind erosion.

The assumption had been made that social and economic problems would take care of themselves if natural forces could be controlled. Social and economic problems were considered recent developments, but he said "our failure to recognize these problems has contributed to their present magnitude."

Another factor was the comparatively recent development of techniques which made quantitative analysis in the social sciences possible. Development of social science research was also limited by the lack of qualified researchers as well as statistical data.

F. B. Mumford, Dean of the College of Agriculture and Director of the Agricultural Experiment Station of the University of Missouri, was assigned the topic, "Responsibility of the Agricultural Experiment Station for the Present Agricultural Situation" for the November 1932 meeting.

He vigorously defended the record of the experiment stations, stating that their primary economic purpose was to provide the

Evicted sharecroppers in Missouri.

knowledge necessary for the farmer to adapt himself to changing conditions. Mumford said that the farmers who were able to hold their own during the depression were those who most closely followed the advice of the experiment stations.

Secretary of Agriculture Hyde in his annual report for 1932 also defended scientific practices. He said that without them the farmer would be dependent upon diseases and pests to regulate output. He wrote that science is more necessary "when prices fall than when prices rise, because cost of production becomes increasingly important."

In his 1933 report, Secretary Henry A. Wallace credited science with enabling man to conquer the problem of producing enough to go around. The special province of economics is, he suggested, to help man utilize this increased productivity.

Because of his background as a scientist and economist, Secretary Wallace was particularly well qualified to recognize and stress the interrelationship of the physical and social sciences.

Research in agricultural economics was being carried on in a number of the state colleges of agriculture in relation to farm management before 1925. Outstanding economists like George Warren of Cornell, Henry C. Taylor of Wisconsin, M. L. Wilson of Montana, and Eric Englund of Kansas were developing agricultural economics as a separate field. Their studies of the depression provided some of the data and ideas basic to the programs of the 1930's.

For example, George Warren's studies of farm prices during the early twenties were used as the basis for the parity formula. Charles L. Stewart of Illinois was instrumental in developing the export-debenture plan, which was introduced into Congress in 1926. M. L. Wilson of Montana was one of the developers and promoters of the domestic allotment plan which was used as the basis for the Agricultural Adjustment Act of 1933.

Agricultural economics became an important area of research after the passage of the Purnell Act of 1925. Besides increasing the funds available for scientific research, this legislation specificially provided for investigations in the fields of agricultural economics, home economics, and rural sociology.

Personnel carrying on economic investigations increased from 100 persons in 1925, concerned primarily with farm management, to more than 230 by the close of the second year covering the whole range of agricultural economics. In 1927, one third of the new projects under the Purnell Act were in economics and closely related lines.

During the first five years after passage of the Purnell Act, a substantial increase was made in economic research projects and by 1930 many of the projects were related to changing national economic conditions.

The total number of projects in agricultural economics increased from 200 to 463. Active marketing projects rose from 43 to 139 and the number of projects on agricultural prices from 9 to 20. Projects in land economics increased from 18 to 31 and those in farm taxation from 5 to 18.

The Purnell Act made it possible for the State Experiment Stations to widen the scope of their work. It provided funds that enabled the stations to greatly increase the number and improve the quality of research projects in agricultural economics, sociology, and home economics.

The Bankhead-Jones Act of 1935 added substantial funds for the conduct of scientific, technical, economic, and other research into laws and principles underlying basic problems of agriculture. Sixty percent of the funds were to be allotted among the States. The funds were not to be substituted for research on other activities underway.

The 1936 report on the work of the State Agricultural Experiment Stations called that year "an epoch in the history of agri-

cultural experiment stations" because of the successful inauguration of effective research under the Bankhead-Jones Act. Research programs and projects were extended in range and scope.

A total of 818 new or revised formal agreements were initiated between the experiment stations and USDA bureaus. All of the State Experiment Stations participated in these projects.

Among the major scientific cooperative research projects with USDA was the development of improved wheat varieties which included Komar developed by the Colorado Experiment Station, Thatcher by the Minnesota Experiment Station, and Canarva by the West Virginia Station.

Fighting Drought

Another area of cooperation was the development of drought-resistant strains of corn and the development of high-yielding hybrid corns by Illinois, Iowa, Indiana, Missouri, Nebraska, Cornell, Ohio and other State Experiment Stations.

Approximately one-sixth of the total state expenditures under the Bankhead-Jones Act was assigned to station projects in agricultural economics. They were concerned with adjustment in production by regions and type-of-farming areas to help farmers adapt to changing economic conditions, with projects on marketing agricultural products, and projects on land use and on soil and water conservation.

Regional and national cooperative research programs started on an emergency basis as a part of the national recovery program in 1934 and 1935 were modified and expanded to meet more permanent requirements.

Projects of regional and nationwide scope directly related to government recovery programs included:

- A nationwide study of mortgage foreclosures, tax delinquencies, and land values in cooperation with the Civil Works Administration, which provided funds
- Studies of subsistence homesteads and part-time farming carried on in cooperation with the U. S. Department of the Interior
- Studies of land-use and land-use policies in cooperation with USDA's Agricultural Adjustment Administration and the Federal Emergency Relief Administration
- Research on credit policies and administration in cooperation with the Farm Credit Administration

• Research projects on the control of production in cooperation with the Agricultural Adjustment Administration

These activities necessitated curtailment of some of the ongoing fundamental research. However, they provided valuable data for future analysis and interpretation and a broader conception of complex problems to be met which needed research.

The value of research training as well as research as a basis for national recovery programs is illustrated by the fact that the new agencies in USDA drew heavily upon state research personnel to carry out the new programs. During 1934, some 600 station staff members took special assignments during the year in connection with emergency activities.

For example, Albert G. Black of Iowa State College was responsible for administering the Corn-Hog Program of the Agricultural Adjustment Administration. In 1939, he was appointed Administrator of the Farm Credit Administration.

When the subject of cooperative research between State Experiment Stations was discussed, during the Land-Grant College Association meetings in 1937, Director L. E. Call of the Kansas Experiment Station said:

> " . . . rugged individualism appears gradually to be giving way to group consciousness as workers have an opportunity to work together and to appreciate the advantages that accrue to them personally from a cooperative attack on a problem. Institutional pride and professional jealously is giving way to pride in the accomplishment of the group as a whole . . ."

The recovery programs organized to combat the depression could not have succeeded without drawing upon the economic studies, the assembled basic data, and the scientific research programs of the State Experiment Stations. In turn, the recovery programs provided new data for future analysis and provided stimulation for a broader conception of complex national and international problems.

A measure of agriculture's recovery from the depression can be seen in the increase of farm income from $4.7 billion in 1932 to $9.2 billion by 1937. This increase in farm cash income was accompanied by an increase in factory payrolls of about the same amount. Since these traditionally had gone up and down in about the same proportion, agricultural recovery was driving back the specter of want in the midst of plenty.

Main Street Pokes Along While Urban Areas Boom

By Joe M. Bohlen, Ronald C. Powers and John A. Wallize

The Main Street of Thompson, Iowa, is waiting.

It's waiting for a small industry with 50 to 60 employees to tire of the big city and move to the openness of Thompson. It's waiting for a young medical student to complete his studies and open a practice there. It's waiting for the decline in farm population to level off. It's waiting for more people to discover the benefits of living in a clean, restful rural community such as Thompson.

The only difficulty is that as Thompson's Main Street waits, the rest of the world is moving by.

Those are the opening words from a profile of Thompson done by Charles W. (Chuck) Walk of the *Mason City Globe-Gazette* in one of a series of articles on small towns in northern Iowa.

Thompson is one of those towns that fits the pattern of shrinking towns and growing cities. Its peak population since the turn of the century was 698 in 1950. The 1970 census showed an even 600 persons—a decline of 14 percent.

In dealing with all the towns of the nation, or even in Iowa, there are many exceptions to the rule, however. Most of the population decline has occurred in small towns under 1,500 population not located near a growing center.

But while you can find many exceptions to the "towns shrink, cities grow" concept, the generalization is still valid. For as Chuck Walk said, while Thompson is waiting, the world is moving by.

The farm population around many small towns has declined.

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Abandoned farmsteads, such as one at left in Washington State, can lead to closed-down businesses in small towns.

Nationally, farm population dropped from 32 million in 1910 to about 9.3 million in 1974. Thus, fewer farmers and their families are trading in towns like Thompson.

Adding to these problems of fewer farm families, and possibly fewer families in town, those who remain often have the money, the transportation and good highways to go to a larger town nearby for shopping. There they find a wider selection of goods, additional services and conveniences, and lower prices. All these things the local merchant could provide with increased volume of business. Instead, business declines for the small town merchant.

The result? Listen to Chuck Walk's description of Thompson's Main Street:

"The empty store fronts are the most obvious evidence of Thompson's 'waiting.' They mark the businesses that have been lost: the drug store, the pool hall, a hardware store, a doctor's office, a barbershop, a couple of implement stores.

"Corner locations are considered prime spots in downtown business districts. The bulk of Thompson's business district is centered in a one-block stretch with four such locations. Two of the corner buildings are empty, a third serves only as a part-time welfare office and the fourth houses a church."

Autos Create Change

Another town featured in the *Globe-Gazette* series was Plymouth, Iowa. It differs. Within easy commuting distance of Mason City, the core city of north-central Iowa, Plymouth has grown. Population in 1970 was 461, up 9¼ percent from 1960. Here's what Reporter Martha Allen found in Plymouth:

"The town is the creation of the automobile. The car turned Plymouth into a suburb, with residents living there, but driving to Mason City for work, shopping and entertainment.

"It is a town with a growing population, but a dying downtown business district . . . all that is left of a once thriving business district with 26 stores 20 years ago is a successful hardware store, one small grocery, a restaurant, a teen center, gas station and auto shop."

A few years ago, economists got heated reactions when they described small towns as dying. Defenders pointed out that there are as many people living in small towns now as there ever were. For the State as a whole, that's true in Iowa, and maybe in the nation. With all the exceptions, it is probably more correct to say that small towns are changing.

Small towns such as Plymouth and Thompson are dying as retail centers. The towns are alive as "bedroom" or retirement communities and convenience centers. But in relation to the rapid growth of the cities in the past 50 years and the need for a larger population in order to obtain low cost specialized services, small towns have "shrunk" even when they show some population growth.

The vacant buildings on small town main streets quickly signal the change that has occurred in the business sector. Less obvious are the changes in the public sector. But the same factors are at work.

Declining rural population and a loss of business in the small towns mean the costs of government and schools must be spread over fewer taxpayers. And just as the merchant needs greater volume, the new advances in education and government—such as special laboratories or computerization—require a larger population base to spread costs and keep them as low as possible per capita.

The "vacant buildings" in the public sector are the unoffered special courses in high schools, high per pupil costs for education, and deteriorating or nonexistent community services.

Busting the "Oat Barrier"

During the first 150 years of America's history, towns and cities both grew in size and number. It has been within the past 50 years that cities continued to grow and towns began to shrink. The change began when the "oat barrier" was broken, as farms changed from animal power to mechanical power.

Mechanical innovations, however, are just one of four general types of change that had profound influence upon farms, farmers, small towns and cities. In addition to mechanical innovations, there were genetic improvements in crops and livestock, and more recently chemical developments which also increased yields and boosted the output of a single farm worker.

Behind all these changes was the fourth category—socio-economic change that allowed the technology to be adopted.

For instance, farming was considered a way of life for centuries, and many people today still cling to that value. But today's believers in that philosophy have modified their attitude to allow change.

Earlier, this "way of life" dictated that the family produce its own food and fiber, and barter or sell the surplus for a minimal amount of goods and services which could not be produced on the farm. The philosophy was one of subsistence and one of the good life working the soil.

The paramount need for food about the time of World War I tended to emphasize production and the development of a businesslike approach to farming. This attitude change permitted the transition to begin from subsistence farming to highly commercialized agricultural operations.

Transportation technology aided changes in social attitudes, however. In the days of limited travel, the neighborhood was a close-knit group. Neighbors were needed and you did little to disrupt the harmony. And in those days it often was more important how things were done, rather than the outcome.

If all your neighbors thought a cleanly plowed and cultivated field was the essence of good farming, you kept a cleanly plowed and cultivated field. Stubble mulch farming could not have been adopted then, even though it might increase production or lower costs.

Communication technology allowed farmers to learn of new ideas and values. Transportation allowed them to select friends from a wider area, and the traditions of "good farming" from the neighborhood view began to give way. With mobility of men and equipment, the farmer no longer was forced to share labor, tools and ideas only with his immediate neighbors.

Another change required was the attitude toward work. The attitude that hard work and sweat was holy and cleansed the soul had to be modified so that management and programming were recognized as "work" also. That attitude is not completely

changed. Recent studies have shown that higher income farmers are those more likely to equate management with work. Lower income farmers tend to be those who still feel that hard work is the only key to success.

This package of mechanical, chemical, genetic, socio-economic change on the farm began to spill over into the towns. It created other socio-economic change. In town, for instance, agricultural supply businesses and firms processing farm products showed new growth.

In 1910, farmers bought only 25 percent of the inputs used in farming, generally providing their own seed, manure, and energy for the animals. In 1970, some 75 percent of all inputs were purchased off the farm—hybrid seed, fertilizer, pesticides, machinery and petroleum. Today, farm supply firms and elevators are often the only major industry for small rural communities in the Midwest.

A farmer hand picking corn with a team and wagon in the early 1930's could pick 80 bushels a day. With an average 20-day picking season, he could pick 1,600 bushels. With 40-bushel per acre corn yields, one man could handle 40 acres of corn.

Then came the one-row mechanical picker, then the two-row, and then the four-row combine and now larger units. With the 4-row combine in the 1960's, one man could pick 1,200 bushels a day, or 24,000 bushels in 20 days. At 80 bushels per acre, that meant one man could handle 300 acres of corn.

Another way to look at the change is in man hours. In the 1920's it took one man about 270 hours to produce a bale of cotton. Today it takes 25 hours. For corn, it took 115 man-hours to produce 100 bushels in the 1920's. Now it takes 6 man hours.

When farmers found they could handle more acreage with the new technology, they expanded. They bought land from their neighbors. Thus, some farmers moved off the land. Average farm size in the United States increased from 174 acres in 1940 to 385 acres in 1974.

It was these changes that set the stage for shrinking towns and growing cities. It required some painful adjustments for people and communities. And all of the adjustment probably is not over yet. Main Streeters in Thompson, Iowa, waiting for the decline in farm population to level off may have a long wait.

Farmers attending Iowa Extension Service meetings indicate they would expand their operations to an average of 544 acres if the opportunity presented itself. This is more than double the

Above, an old hand planter is contrasted in 1937 with the latest in corn planting equipment at that time, in New Jersey. Below, even the shape of farmers' fields is determined by today's circular irrigation units, as in this Wisconsin operation. The irrigation unit covers 160 acres of potatoes.

average size of Iowa farms today. Only a significant change in national policy is likely to alter the basic trend to fewer and larger farms.

There has been more change in farming in the last 40 years than in the previous 4,000. Such massive change was bound to affect people and families in many ways. Through modern communications, farm families learned of the advantages of smaller families. Without diversified agriculture, the many chores for youngsters disappeared. Machinery required adult skills. Large familities were no longer needed. And rural population dropped further.

Exodus to the Cities

For those who left the farm and farm work, the cities often offered the greatest opportunity. Most often it was the young who made the move, while those who retired from the farm tended to stay nearby. Thus the rural areas and small towns tended to have more older residents, dropping birth rates there even more.

It is not uncommon in many small towns for 20 to 25 percent of the population to be over age 65. More than a third of the houses in these towns may be occupied by the elderly.

In recent years as many as 10 percent of the counties in the United States have had more deaths than births. A "natural decrease" in the population, demographers say. As one resident of such a county put it: "We've given up on the First Baby of the Year Award. The suspense wears off around Valentine's Day."

This trend further complicates the problems of small towns. Elderly people often need additional community facilities, particularly transportation and health services. Yet the declining population of these areas is putting pressure on services, and the number and quality of services tends to decrease rather than increase.

Many communities hoped that industrial growth would replace the lost jobs in agricultural production. In some cases, there has been respectable industrial growth. But the amount of industrial and agricultural services growth has not been adequate in most communities to offset the decline in agricultural production employment.

Most of the new industrial growth took place in the cities, or nearby, where transportation, workers and services already existed. This growth brought even more people to the already congested areas.

Mechanical cotton picker.

While the small towns wrestle with problems of decline, cities struggle with problems of growth. Daniel Bell, a Harvard University sociologist, estimates that it costs $18,000 per person to provide each new city resident with the "infrastructure"—schools, streets, sewer, water and governmental services.

The problem of imbalance between rural and urban was not totally ignored by the State Agricultural Experiment Stations as it developed. But neither was there great public demand nor support for research on problems of communities.

Most of the early work on communities was limited to descriptive case studies. C. J. Galpin's 1915 research in Wisconsin, "The Anatomy of a Rural Community," is a classic example.

Population studies of rural areas in the 1940's by the Bureau of Agricultural Economics, U. S. Department of Agriculture, indicated general trends. And some population studies indicated the developments that were to come 20 years later, but apparently received little attention.

In the 1950's there was a wave of social participation and formal organization research, including a study of agricultural

Georgia town that once thrived on the cotton business.

cooperatives and farm organizations. Much of the social participation research examined adoption of new ideas and focused primarily on agricultural technology. Some of it can be applied to community problems now, but that was not its original focus.

Economic and population base studies became more sophisticated in the 1960's, compared with the earlier community case studies. They provided a base for analysis of the wave of change that now engulfs us. But much of the research on the effect of change at that time was concerned with farm families, rather than communities. There were studies of farm labor, jobs for farm youngsters, and entrance into farming.

With the growth and congestion problems of the cities becoming more pronounced in the 1960's and the problems of rural areas intensifying because of de-population, attention was focused on obtaining a better balance in growth. Rural development was on the horizon in the 1950's, but strong emphasis has come only in recent years.

The advantages of a more balanced rural-urban growth can be seen in many ways. In the cities, there are crowded classrooms and inadequate school buildings. In rural areas, school buildings often are being used as machine sheds and for grain and crop storage.

But like the decrease in the number of farms, only a significant change in national policy regarding industrial location or population distribution is likely to change the basic trend of shrinking towns and growing cities.

With today's awareness of problems, more industry may be

lured to the rural areas. But the amount of industry needed to offset future changes is massive, without considering past population decline in the rural areas. It isn't likely that there are enough new industries or branch plants to solve the problems of all the nation's small towns.

Nor will industrial growth be the magic solution for all the problems of all small towns. Many small towns now attract residents because of low living costs and low taxes. Sewer and water systems may be barely adequate. Revival of these towns with growth will cause increased competition for housing, and require upgrading of sewage and water treatment plants. Some of the low taxes and low cost living would evaporate in the heat of growth.

Consequently, many small towns must adjust to the situation. One way to solve problems relating to declining population is to put the "community" into a wider economic base—to provide goods and services over a wider area to spread the cost. In practical terms, this means consolidation of schools, government, medical services, shopping centers, and the merger of churches. It means, too, that rural residents may have to drive farther for services.

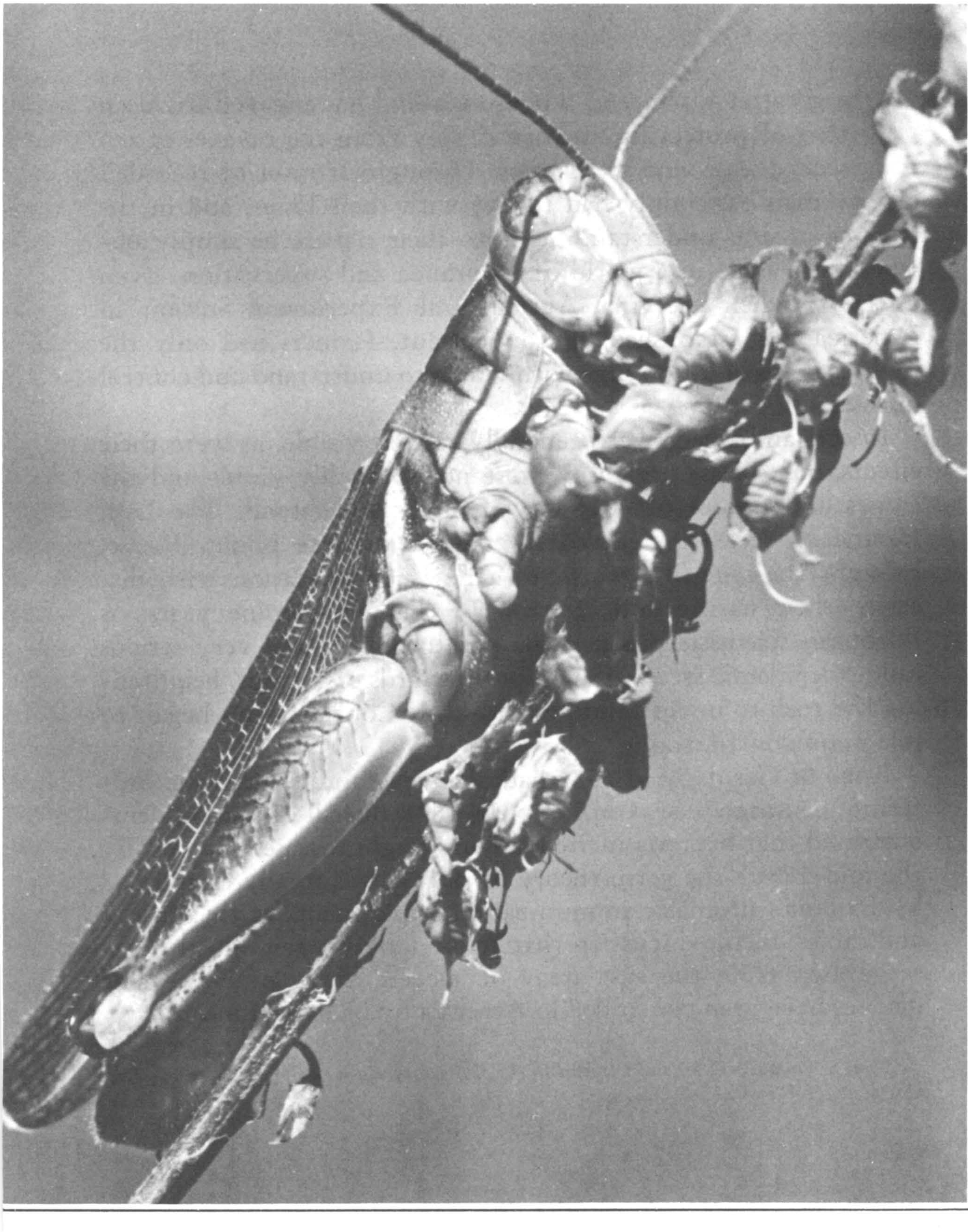
Many of these types of changes have met resistance in the past because so much of the early life centered around the town. People don't want to lose "our" school, our church, our doctor, or our township, town or county officials.

Just as with farming 30 years ago, the technology exists for community change. The major puzzle for rural development seems to be the change in attitudes necessary to allow adjustments in communities.

Our concerns with the problems and adjustments should not let us overlook the success that has brought this situation about. Since the oat barrier was shattered, farm incomes have risen, agricultural productivity has increased, and there has been tremendous industrial development. For some, the transition from subsistence farming to a place in urban society has meant a better life. For others, the transition may have been a bitter adjustment.

The challenge today appears to be to ease the problems of congested metropolitan areas while halting the decline of small towns; preserving the greatest benefits of both rural and urban living; and allowing individuals the widest possible latitude in making personal adjustments that will provide them with the life style they seek.

FOOD DESTROYERS



Plant Disease Toll Is Cut With Resistant Varieties

By Glenn S. Pound

The greatest warfare in which mankind has engaged has been that of protecting his food supply from the ravages of insect, disease, and weed pests. Throughout most of recorded history man has simply had to live with these losses, and in the absence of any understanding as to their nature he simply observed and lived in a world of ignorance and superstition. Even in 1875, when the first Agricultural Experiment Station in America was established in Connecticut, farmers had only the slightest basis of knowledge with which to understand and control diseases.

Insects and weeds were generally readily visible, as were their effects, but disease organisms were not so readily visible and the causes and nature of disease were little understood. The Irish famine of 1846–48, caused by the potato late blight disease, brought the scientific world to a new confrontation with diseases—their nature and control. In the post-famine years, as European scientists pursued the potato disease, the very serious mildew epidemic struck the grape vineyards of Europe, heightening the rush to understanding of disease. Contributions began to pile upon contributions.

Koch of Germany in 1876 had identified and isolated the bacterium causing anthrax in sheep. In 1878 Burrill of Illinois demonstrated that bacteria incited the fire blight disease of pears. By the mid-1880's the germ theory of disease was finally established by Pasteur's dramatic immunization experiments with anthrax and rabies. In the discussion that follows, only a few illustrations are drawn from the vast array of success stories of how plant diseases have been controlled in America by biological means.

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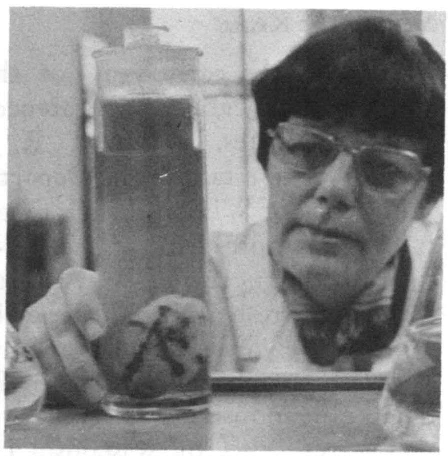
It has been the use of genetics in plant breeding that has resulted in effective control of most of our more serious diseases of crop plants. In 1866 the Austrian monk, Gregor Mendel, performed some pollination experiments in garden peas that demonstrated the simple inheritability of certain plant characters. This renowned discovery was little used until about 1900. Its first use in regard to breeding for disease resistance was by Biffen in England. When Biffen reported that resistance to yellow rust in wheat was inherited as a simple character, his finding was not widely believed but it was both a goad and a guide to similar studies of a number of disease problems.

By 1900, the cotton lands of the Sea Islands off the Carolina coast had become heavily infested with the *Fusarium* wilt fungus and this rapidly spread to the upland cotton belt of the mainland. The U. S. Department of Agriculture (USDA) added W. A. Orton as a young scientist to its staff to study the problem.

Orton, beginning with material already under observation and selection by farmers, through the use of simple plant selections soon developed highly resistant varieties of sea island types of cotton. His selection work was extended to upland cotton varieties and, in cooperation with breeders in the cotton States of the Southeast, a number of resistant varieties were developed.



Left, Oklahoma biochemists inject bacteria into cotton plant to try to induce hypersensitive reaction, plant's defense mechanism against bacteria that cause cotton blight. Right, a 19th century Connecticut pathologist etched his initials on this potato in the field with paste from fungus he believed caused potato scab. When he dug tuber in fall, he found his monogram neatly etched by the obliging fungus, and proved his case.

With success against the cotton wilt disease at hand, Orton directed his attention to the *Fusarium* diseases of watermelon and cowpea. In developing the Conquerer watermelon, he did not follow the mass selection technique used in cotton but crossed the resistant but nonedible citron with susceptible watermelons and selected resistant plants from the hybrid progenies. This was one of the first attempts of a breeder to produce a new variety by genetical synthesis, a technique to be used over and over again in subsequent years.

The Conquerer melon did not have enough desirable characteristics for it to become popular with farmers but it provided resistant germ plasm from which many other varieties were to be derived.

At the same time Orton was conquering wilt of cotton in the Southeast, H. L. Bolley of North Dakota was studying a very similar *Fusarium* wilt of flax in the northern plains. Shortly after 1900, the resistant varieties North Dakota Resistant 52, North Dakota Resistant 114, and Bison were developed by mass selection from plant survivors on badly infested soil. Bolley's achievement in bringing flax wilt under control stood beside that of Orton's in historical significance of plant disease control by use of resistant varieties.

Saving the Kraut

Also, in the early years of the century, a *Fusarium* disease (yellows) of cabbage threatened the cabbage industry of the Northern States. In 1909, L. R. Jones moved from Vermont to Wisconsin to establish the Department of Plant Pathology at the University of Wisconsin. His first attention was given to the cabbage yellows problem.

With the success of W. A. Orton, whom Jones had trained at Vermont, fresh in mind, Jones began selecting resistant plants from severely infested fields and by 1916 the first yellows-resistant variety of cabbage (Wisconsin Hollander No. 8) was released. The kraut industry was saved.

The resistance of Wisconsin Hollander was found to depend upon air temperatures being 25°C or below, and in excessively hot summers it was not satisfactory. That led J. C. Walker of Wisconsin to search for a more stable resistance, which he readily found in cabbage and isolated by controlled bud pollination. This resistance was a single dominant factor and was easily manipulated to produce varieties which were virtually immune.

During the period 1920–1950, a large number of resistant cabbage varieties were developed to meet the varying and changing demands of the kraut and fresh market industry.

Resistance to other cabbage diseases has been added to *Fusarium* resistance and many varieties today carry resistance to yellows, mosaic, clubroot, physiological tipburn and black rot. Many other *Fusarium* diseases of crops have been brought under control by development of resistant varieties, including tomato, radish, spinach, pea, muskmelon, flax, and others.

As soon as the yellows resistant varieties were released, the kraut industry was placed in a second jeopardy by two new diseases, black leg and black rot. These diseases were carried internally by the seeds and were regularly transmitted by seeds grown in Europe or the eastern United States.

Clayton (New York) and Walker (Wisconsin) both demonstrated that seed could be freed of contamination by soaking the seed in hot water, but this often resulted in losses in germination. Walker showed that seed produced in the Puget Sound area was free of contamination because of the absence of splashing rains required for moving the fungus spores onto the seed pods. For over 50 years this has been the standard control of the black leg disease.

Use of semi-arid areas for production of disease free seed has been subsequently highly successful in control of a number of important seed-borne diseases, particularly in bean, pea, cucurbits, and crucifers.

Those Tricky Rusts

The control of Fusarium wilt diseases has been a much simpler task generally than control of the rust diseases of wheat, due to pathogens of less genetic variability. But the wheat rusts have yielded to the breeders, nonetheless.

American wheat development began by importations of established varieties from Europe. The Hard Red Winter wheat belt was established with the introduction of Turkey. The Durum wheat belt was established with the introduction of Arnautka to the Dakotas. The Soft Red Winter Wheat belt was established by introducing Mediterranean. And the White Wheat areas were established with the introduction of Baart from Australia. Mark Carleton of USDA pioneered in introducing hard red winter wheats and durum wheats to the United States from exploration trips to Europe and Russia.

Some of these varieties were improved by farmer selections and in the late years of the 19th century some varieties were started by hybridization, again with the early work being done by farmers.

Perhaps the most important single wheat of all history was that of a plant of spring wheat from a winter wheat variety imported to Canada from Scotland by David Fife. From this one plant the Red Fife variety was developed and introduced to the United States in 1860. Red Fife in turn was used by C. E. Saunders of Canada to develop Marquis, a variety of superior quality and whose germplasm was to be passed on to Ceres, Hope, Marquillo, Reliance, Thatcher, Sturgeon, Comet and other varieties which brought great stability to our wheat belts because of their improved quality and disease resistance.

The rust diseases of wheat, particularly black stem rust (*Puccinia graminis tritici*) were baffling to the wheat breeders. A variety resistant in one location or at one point in time often was susceptible under different conditions. It had been shown (1894) by Erikkson and Henning of Europe that the black stem rust fungus existed as a number of subspecies, each of which parasitized a specific host species such as wheat, rye, oats, etc. In 1917, Stakman and Piemeisel (Minnesota) discovered that the organism existed not only as a number of subspecies, but also as a wide range of physiological races within a subspecies which were pathogenic to specific varieties of the host plant.

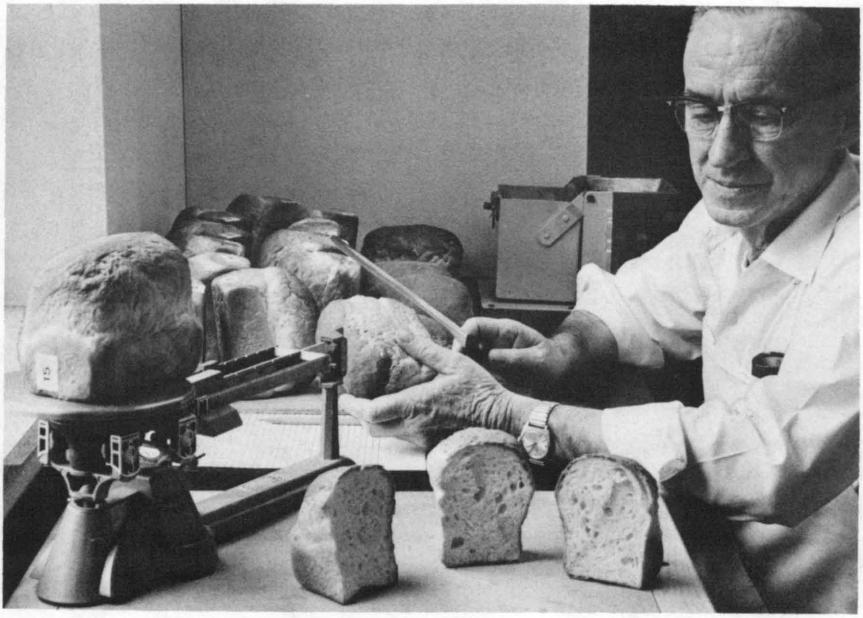
Sex and the Barberry

It had been known since 1865 that the fungus spent part of its life on the common barberry plant. It is on this plant that the sexual cycle of the fungus occurs and where new races develop when genetically different nuclei come together in sexual fusion.

This information provided the breeders with an understanding of how a popular resistant variety suddenly became susceptible and of the importance of the barberry in the ecology of the disease.

In 1918, a massive barberry eradication program was launched in the United States, a program which has been maintained to the present, and one which has brought considerable stability to the breeding programs by reducing the potential number of pathogenic races.

As previously mentioned, the introduction of the Marquis variety to the United States in 1913 provided breeding stock of



Milling and baking characteristics of breeding lines of wheat are thoroughly tested before new varieties are released to Oklahoma growers.

superior milling quality and of early enough maturity to permit it to escape a considerable amount of rust. In 1918, L. R. Waldron (North Dakota) crossed Marquis x Kota from which he developed the variety Ceres which was released in 1926.

Ceres carried the superior quality of Marquis and was resistant to certain races of *p. graminis tritici.* It rose rapidly in popularity and by 1935 was grown on 5 million acres, centered in North Dakota. But Ceres was not resistant to all races of black stem rust and after 1935 its popularity began a sudden decline because of the buildup of race 56.

The breeders were now working ahead of the rust and as Ceres ran into trouble, two new varieties, Marquillo (Marquis x Iumillo) and Thatcher (Iumillo x Kanred x Marquis) were released in 1929 and 1934, respectively, by H. K. Hayes (Minnesota) and his State and Federal colleagues. These two varieties of hard red spring wheat had a much higher level of stem rust resistance contributed by the durum parent, Iumillo.

Still another wheat variety which filled a great need by lifting rust resistance to a still higher level was that of Hope, introduced by E. S. McFadden of USDA (South Dakota) in 1926. Hope was derived from a cross of Marquis x Yaroslav emmer and it pos-

Left, experimental wheat in these Oklahoma plots has resistance to leaf rust disease. Scientists used X-rays to "break" chromosomes of wheatgrass, then transferred to wheat the part carrying gene for rust resistance. Right, Washington State pathologist inspects wheat roots for disease. He grows wheat in mist chambers without soil or water.

sessed the highest level of resistance to stem rust of any previous variety. In addition it was resistant to leaf rust, bunt and loose smut. Hope was never grown widely because of other factors but was widely used as breeding germ plasm.

The breeders and pathologists had thus learned to incorporate resistance to a large number of rust races in a single variety, and a period of stability was experienced during the 1940's. In the late 1940's a new race (15B) was found and since all commonly grown varieties were susceptible to it, a new rust epidemic was feared.

This fear became reality as race 15B built up; and in the early 1950's losses in the Dakotas and Minnesota were devastating.

Breeders moved rapidly to incorporate resistance from some Kenya wheats into their breeding lines and by the end of the 1950's the race 15B epidemic had been brought under control.

The 15B epidemic resulted in new realization of the need for international approaches to rust control in regard to detecting the existence and location of rust races and resistance to these races. International nurseries have been established whereby the world can have a free flow of this much needed information.

A similar history of control of other rusts, smuts, and mildews of wheat and of our other grain crops, particularly barley and oats, can be written. Pathologists and breeders have been singularly successful in cutting the losses and improving yields and quality.

Curly Top and Sugar

The United States has extremely limited possibilities of sugar cane production because of its temperate climate and thus has had to rely on sugar beets for domestic production of sugar. Technology for sugar beet production was imported from Europe, and by the early years of this century sugar beets were grown widely in our Western States. The industry was soon beset with heavy losses and even area wide crop failures due to curly top disease, a virus disease transmitted by leafhoppers.

This important industry was faced with total failure and in 1929 the U. S. Congress appropriated funds for research on curly top and its insect vector. Under the leadership of Eubanks Carsner of the USDA, experiments were begun to discover a source of curly top resistance. Initial efforts were directed at varietal improvement by selecting individual resistant plants from a heavily infected field. By this method a tolerant variety was released in 1934, named U. S. No. 1 and came into widespread use by the mid-Thirties.

U. S. No. 1 had been rushed into use, purely as a stopgap measure, because of the emergency. With more time, U. S. 33 and U. S. 34 varieties were developed by mass selection within U. S. No. 1. These varieties were a marked improvement in resistance and agronomic characteristics.

Pure line breeding was soon employed and resistance to *Cercospora* leaf spot was added with the first resistant leaf spot variety (U.S. 217) being released in 1938. Next, hybrids were produced, the first being U. S. 200 x 215, which not only provided resistance to the two diseases but possessed vastly superior agronomic qualities. The United States was thus assured a significant domestic production of sugar.

An indication of the advance made by these varieties is that in 1934, over 85 percent of the planted sugar beet acreage was abandoned because of curly top, and the average national yield was 4.9 tons per acre. In 1941, itself a bad curly top year, 97 percent of planted acreage was harvested and national yields averaged 13.5 tons per acre.

Cold Potatoes

Disease control in vegetatively propagated plants is particularly difficult because of inherent "seed" transmission and the story of bringing potato diseases under control is different. A number of virus diseases, such as mosaic, latent mosaic, rugose mosaic, and leaf roll became so widespread in potato in both Europe and America that seed stocks were thought to have "run out", or degenerated.

About 1914, W. A. Orton of USDA travelled to Europe to survey the disease picture on the continent. On his return he advocated an approach to control by isolating virus-free tubers and growing them under conditions whereby they could be certified as being disease-free.

Pathologists made detailed studies of the virus complex and gradually identified the causal viruses. Tompkins and Johnson (University of Wisconsin) showed that mosaic symptom expression was markedly dependent upon plant exposure to air temperatures of 23 °C or lower, and that even short exposures to such temperatures brought out symptoms. At higher temperatures symptoms were masked. This discovery made greenhouse culture very important in assaying seed stock. It also meant that samples of potatoes in storage could be planted out in the South in winter or early spring and their virus content determined before planting time in the North.

The Northern States became the seed producers because of their better isolation and more severe climate which would more likely kill insects transmitting the viruses.

Several State Agricultural Experiment Stations developed foundation seed farms on which disease-free mother stock would be developed for sale to growers who would increase the stock for retail sale. Many private firms offered similar services.

On these farms, which had strict geographic isolation, disease-free stocks were built up. Increase of the foundation stock is grown by the primary producers under field inspection. Further inspection and assay are made of seed tubers in storage by greenhouse, or southern field plantings. Only stocks maintaining disease freedom in all these steps are certified as disease-free.

Since 1950 the potato fields of America have been remarkably free of virus diseases and bacterial ring rot, and trouble arises only when growers attempt to compromise with sanitation requirements.

The Vets Save Our Beef and Milk, and the Bacon

By Rue Jensen

During the years 1850 to 1930, some highly successful veterinary research was originated. Of all the advances made, five were especially outstanding.

These five notable successes were: Eradicating bovine pleuropneumonia, brucellosis immunization, hog cholera immunization, eradicating cattle tick fever, and invention of the rumen fistula—a window on the stomach of animals.

The successes were great ideas, important because of their national scope, lasting effects and broad benefits to both man and animals.

The great ideas were helped along by the origination of influential organizations for veterinary research: the Federal Bureau of Animal Industry and the State Agricultural Experiment Stations. Each of these organizations employed veterinary scientists to research diseases and solve the problems of livestock health.

Although many experiment station scientists concentrated on problems within their individual states, they collectively researched the animal diseases of the Nation.

In addition, State and Federal workers collaborated in their investigations. They frequently studied different aspects of common problems. Cooperation came from scientists in regional areas and from national and State conferences on technical subjects. In disease eradication programs, State and Federal cooperation was necessarily close and detailed.

One of the first problems tackled was the disease called contagious bovine pleuropneumonia, or CBPP. This disease had ravaged the cattle of most continents. It decimated European

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herds in the 19th century. Through commerce in sick animals, the disease spread first to Australia, then to South Africa and finally to the United States.

CBPP prevailed in the United States for a half century. It was brought into this country in infected European cattle at New York, New Jersey and Massachusetts in the 1840's and 1850's.

Once in those areas, the infected animals transmitted the disease to local herds. From these areas, cattlemen traded and transported newly infected cattle, thus disseminating the disease further.

Initial spread was along the East Coast. But by 1883 the disease had shown up in Ohio and later moved on to Kentucky, Illinois, Indiana and Missouri. Local alarm developed into national concern when in 1887 the disease entered Chicago's Union Stock Yards, the national center for cattle trading.

It became obvious to owners of infected herds that CBPP was costing them a great deal of money. The direct cost was dead cattle. The death rate was from 30 to 50 per cent in an infected herd.

Indirect costs were a diminished meat and milk production. Overall, the prospects for great and continuing losses were startling. These economic realities were the impetus for disease-control measures.

Public opinion and public policy naturally favored official programs to control and eliminate the disease. During early decades of the epidemic, some infected states began containment plans. But the plans failed because of inadequate state statutes, appropriations and personnel. The disease continued to spread steadily and take its economic toll.

Colorado veterinarians in the field.

Animal is tested in Colorado project on brisket disease, high altitude disorder of heart and lungs.

Despite State failures, proponents for control were sure CBPP could be eradicated. They understood that the causative germ lived in the lungs of infected cattle, that the germs left infected cattle in exhaled air, and that the germs entered the lungs of susceptible animals with inhaled air.

They reasoned, therefore, that identification and destruction of diseased cattle would remove the sources of infection. These facts were central to their idea for eradication and to their recommendations for action.

In 1887, Congress, in response to recommendations, doubled the appropriation for the new Bureau of Animal Industry and increased its authority. This agency in the U.S. Department of Agriculture was directed to initiate and carry out a national CBPP eradicative program.

The Bureau immediately hired personnel for the job and instituted its plan. The operating principles were: 1) quarantine suspicious herds, 2) examine all individual animals, 3) purchase and destroy all affected animals, 4) clean and disinfect contaminated properties, and 5) maintain strict herd quarantine for three months after the last evidence of infection.

Progress was discernible within a few months. After five years, the devastating disease disappeared.

In a short time and at modest cost, officials eradicated CBPP and brought benefits to all—to American cattlemen, a livestock industry of 125 million gainful animals; to American consumers, a plentiful supply of nutritious beef; and to American environments, an animal component rid of contagious and debilitating disease.

Products Infect People

The second of the great ideas was to immunize cattle against brucellosis with a live but harmless strain of the causative bacteria.

In America, bovine brucellosis was an important disease. It caused abortions in cattle, and its wide distribution and general prevalence cost America about $85 million annually.

Brucellosis is an acute or chronic contagious disease of domestic animals and people. The cause is bacterial germs of the genus *Brucella*: *Br. abortus* in cattle, *Br. suis* in swine, and *Br. melitensis* in goats and sheep.

Each of the species occasionally infects people.

In bovine brucellosis, the individually infected animal was the factor crucial to whether the disease would be maintained, spread or eliminated. At the time of abortion the causative germ was shed into the environment in vast numbers through aborted calves, uterine discharge, or milk.

The disease generally spread to other cattle by germ ingestion and inhalation. Infected raw meat and raw milk used as food spread the disease to the consuming public.

Affected cattle reacted to the disease by producing specific antibodies in their blood. Consequently, technicians were able to identify infected animals by a simple blood test.

I. F. Huddleston of Michigan first suggested using live strains of low virulence to immunize cattle against field strains of high virulence. Investigators rapidly researched this principle.

J. M. Buck of the U.S. Department of Agriculture tested five separate vaccines made from different live strains. One, designated strain 19, was safe to use and effective for immunizing, with stable features, and feasible for manufacture.

Investigators in the United States, Britain and the Soviet Union found and evaluated other low-virulence strains. Although some possessed considerable value as immunizing agents, none equaled strain 19.

As a result, strain 19 was standardized and manufactured into vaccine. Millions of doses were used on American cattle and millions more on cattle and sheep of other livestock-producing countries. Veterinary scientists had found a useful vaccine against bovine brucellosis.

During early decades of the 20th century, at least 6 per cent of American cattle developed brucellosis, aborted calves, and spread germs in their milk. About 5,000 people annually con-

USDA and California scientists teamed up to find out if TC-83 vaccine gives long-lasting immunity against dreaded horse disease VEE, Venezuelan equine encephalomyelitis, and decided it did. Top right, inspecting electronmicrographs of virus. Top left, veterinarian at work. Mosquitoes like one in circle carry VEE from south of border. Above right, allowing mosquitoes in chamber to feed on horse. Above left, filling trays for test to identify virus strains.

tracted the disease, suffered its miseries and endured its incapacitations.

Because of two events—vaccine availability and disease prevalence—State and Federal officials initiated a brucellosis control and eradication program in the 1930s which reduced the disease to a low level.

Eventually, brucellosis, a killer of calves and a maker of miseries, will disappear from American cattle and people.

The third great idea was immunizing swine against hog cholera with virulent virus and immune serum.

The first American outbreaks of hog cholera were in Ohio in 1833. From there it spread to all states. Before vaccine development, annual cholera losses in the United States ranged from 4 to 10 per cent in swine numbers and from $11 million to $40 million in market value.

Virus Lethal

Hog cholera, an acute contagious disease, is characterized by fever and hemorrhage and is caused by a lethal virus. Its national distribution, high incidence and decimating mortality made hog cholera the major disease of pigs and a serious concern to the entire industry.

Following establishment of the Bureau of Animal Industry, considerable research was concentrated on the cause of hog cholera. In 1885, Dr. D. E. Salmon, the first chief of this Federal bureau, discovered the bacillus *Salmonella suipestifer* in cholera-sick swine. He assumed the bacillus was the primary cause of hog cholera.

However, some disturbing information contradicted Salmon's interpretation: Animals recovered from natural cholera were immune to new attacks, while those recovered from the bacillus-induced disease were susceptible. Also, the bloods of animals affected with cholera were infectious to susceptible swine, but the bloods of animals affected with the bacillus-induced disease were not.

These discordant facts in 1903 led E. A. de Schweinitz and M. Dorset to perform the crucial experiment: They passed blood from an animal sick with cholera through bacteria-retaining filters and obtained a bacteria-free portion and a portion containing *Salmonella suipestifer*.

These two parts, separately injected into susceptible swine, each induced hog cholera. By this simple procedure the scientists deter-

mined that a virus, not *Salmonella suipestifer*, caused the disease.

Soon after the virus was discovered, the research program was moved to Iowa where scientists, including C. N. McBryde and W. B. Niles, pursued the principle of immunization with virulent blood and immune serum. Most affected pigs died, but experimental hog No. 844 had recovered from natural cholera. The scientists injected into this animal incremented amounts of viral blood. Its tolerance to the virus indicated hyperimmunity.

Eleven days after the last injection the researchers collected serum from the hyperimmunized animal. In another crucial experiment they simultaneously injected some cholera-susceptible swine with the hyperimmune serum and viral blood, and others with viral blood only. Animals receiving both serum and virus remained healthy, and those receiving virus only contracted the disease. From this successful experiment a scientific base for immunizing with serum and virus emerged.

Veterinarians applied the vaccine to commercial swine by simultaneously injecting each animal with correct amounts of viral blood and immune serum.

The injected virus stimulated the animal to produce its own lasting immunity, and the immune serum temporarily protected the animal against the disease-producing virus. The vaccine was developed about 1906 and soon thereafter became commercially available.

Early in the research program, however, officials recognized the disadvantages of using virulent virus as part of the vaccine. The virus alone could infect and kill swine. Therefore, it could indefinitely maintain hog cholera within an environment.

Because of these dangers, Dr. Dorset investigated vaccine safety and discovered that a mixture of crystal violet—a dye, and glycerol—an alcohol, did inactivate the virus without destroying its immunizing ability. With this research, a scientific base for the crystal violet vaccine also emerged.

The crystal violet vaccine was developed in 1935 and scientists made it available years later.

The simultaneous vaccine, used extensively for more than 50 years, enabled the swine industry to exceed 60 million animals in the United States and 500 million animals in the world.

Conscientious use of the vaccine reduced losses to a low level. Later, workers substituted the crystal violet vaccine for the simultaneous vaccine. The change rapidly reduced the number of cholera outbreaks, and will lead to eradication of the disease.

A First for the Tick

The fourth great idea was the discovery that cattle tick fever was spread by the bite of a tick.

During the 19th century, cattle tick fever was widespread through the southern United States. It caused extensive economic losses estimated at $40 million annually.

Before 1891, southern producers moved vast herds of cattle into the West, Midwest and Northeast for pasture and market. Except for the presence of numerous parasitic ticks, the cattle appeared healthy.

Local veterinarians and cattlemen noted, however, that native cattle contracted tick fever after contact with the southern animals or after grazing on land which earlier had been grazed by the southern cattle.

Soon after establishment of USDA's Federal Bureau of Animal Industry, three of its veterinary scientists—Drs. T. Smith, F. L. Kilborne and C. Curtice—initiated a research program on cattle tick fever.

In 1889, they microscopically examined fresh and stained blood from an animal sick with the disease and found paired protozoan parasites in the red cells. Subsequently, the scientists readily found the parasites in the blood cells of sick animals in all of 14 disease outbreaks but none in the bloods of cattle from healthy herds.

Furthermore, by injecting blood containing the protozoa into healthy cattle, they produced the disease and found the organisms in the injected animals' blood cells.

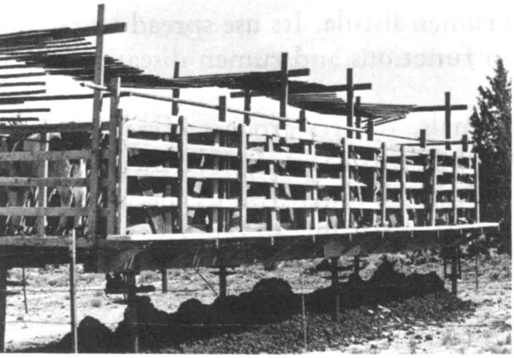
With this convincing evidence, Smith and Kilborne in 1889 declared the protozoan as the specific cause of cattle tick fever and eventually gave it the name *Babesia bigemina*.

The workers then turned specifically to the ticks. During a four-year study they repeatedly demonstrated that:

—When susceptible cattle came in contact with tick-infested southern cattle, they obtained some ticks and contracted the disease.

—When ticks were removed from southern cattle and placed in pastures containing susceptible cattle, the animals acquired ticks and contracted the disease without any contact with southern cattle.

—When all ticks were removed from infected southern cattle, the disease didn't spread to other suspectible animals living with southern cattle.



These calves spent summer on tick-proof platform five feet in air, in Oregon study on carriers of anaplasmosis, a major bovine disease. Control animals were allowed to graze around platform. Under conditions of the experiment, ticks, rather than flying insects, appeared to be the principal transmitters of the disease.

—When tick larvae from laboratory-hatched tick eggs fed on susceptible cattle, these animals contracted the disease.

Between 1889 and 1892, the veterinary scientists found the cause of cattle tick fever—a parasitic protozoan. In addition, they discovered the cause was biologically transmitted by a tick.

Both events were crucial to understanding and controlling this important disease. The first discovery of disease transmission by an arthropod had epochal dimensions for veterinary medicine, human medicine and general biology. Since then, other investigators found that many diseases are transmitted by ticks and insects.

In 1906, officials began a program for wiping out the tick along with cattle tick fever from the United States. At that time, 985 counties in 15 States were infested.

The officially approved method was to quarantine infested areas and submerge all cattle in an arsenical dip at two-week intervals from March through November. During this time, all ticks should have died either from dipping or starvation.

Many areas rapidly eradicated ticks and removed their quarantines. But others—because of ignorance, prejudice and provincialism—sabotaged the program and delayed objectives.

However, after 50 years, all obstacles were overcome and cattle tick fever was eliminated. Once again, consumers, producers and environments benefited.

The fifth great idea opened up new avenues of research. It was the idea of studying digestion through a hole in a cow's stomach.

Cattle and camels, goats and gnus, sheep and saiga (a sheeplike antelope) have rumens. The rumen was an enigmatic fore stomach until 1921 when two veterinary scientists—Drs. A. F. Schalk and R. S. Amadon—cut a window and looked in.

The investigators, working at the North Dakota Agricultural

Experiment Station, invented the rumen fistula. Its use spread to all States and nations where rumen functions and rumen diseases were studied.

Using goats as experimental animals, the researchers created fistular openings in order to easily observe and accurately measure digestive movements of the rumen. Through the fistula, an artificial opening of any diameter, they were able to remove any portion of the contents and to insert scientific instruments.

They obtained the information, the original records on ruminal contractions, and recognized that many other types of information about stomachs could be obtained through the use of fistulas.

Following development of the ruminal fistula, numerous scientists used it in studies of rumen digestion, syntheses and diseases. Vast amounts of information were obtained, and these understandings were used to improve the health and efficiencies of ruminants to produce foods of animal origin for human consumption.

Investigations determined, for example, that the rumen, producing no digestive enzymes itself, contained 2 to 20 billion bacteria per gram of contents. These organisms did produce enzymes that digested carbohydrates, proteins and fats. Plants commonly used as feed for ruminants contained sugars, starches and celluloses.

The ruminal bacteria converted them to organic acids which, when absorbed, were metabolized as a source of energy. Although sugars and starches could be digested by people, celluloses could not.

In a similar way, many ruminal bacteria absorbed dietary ammonia which they used as a source of nitrogen in synthesizing protein for their own protoplasm. Many such bacteria passed into the small intestine where on their death they released these proteins for digestion, absorption and tissue building by the animal.

The simplicity of the fistula made it possible to use it among all members of entire groups of experimental ruminants. To avoid unnecessary loss of contents and heat, the workers closed the fistula with a removable plug.

The presence of the simple fistula or the passing of instruments through the opening caused no discomfort, inconvenience or adversity to the affected animal.

Using fistulated animals, scientists discovered how cattle and camels, goats and gnus, sheep and saiga were able to graze grasses, that great resource of the temperate zones, and convert these grasses to meat and milk.

Antibiotics Curb Diseases in Livestock, Boost Growth

By Robert H. White-Stevens

Two ears of corn, two bushels of potatoes, two pigs, two calves, two chickens, two turkeys now grow where but one grew before. This has been achieved through the concerned work of many people in all walks of science and farming.

Among the several scientific discoveries which substantially contributed to the abundant yields of our meat, egg and milk production was the astonishing discovery in the early 1950's of the "antibiotic growth effect" on livestock. It was at first unexpected, illogical, and baffling, but enormously exciting for it opened new vistas of research in animal science.

"Great scientific discoveries result from the exposure of a natural phenomenon to an enquiring mind," said Louis Pasteur, and so it was with the whole field of antibiotics commencing with the discovery of penicillin, the now familiar wonder drug.

Thousands of bacteriologists often had seen the blue mold *Penicillium*, contaminating their isolation plates and rendering them tainted and useless. They, too, had seen the blank (inhibition) areas around the growing molds where the bacteria failed to grow.

Yet it took the genius of an Alexander Fleming to recognize, in 1928, that the mold must be producing a substance which prevented the bacterium from growing—in fact, an "antibiotic".

It took a decade, however, before this laboratory curiosity found practical application in disease control and another five years before it could be produced in sufficient quantity to be available to all at low cost. In time, incidentally, to save thousands of lives in World War II.

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The antibiotic era was born with Fleming's discovery, and the search began for other natural compounds with antigerm activity that also were safe at effective doses for use on man and the higher animals—livestock and pets.

In 1944 the soil microbiologist Selman Waksman and his associates, at the New Jersey Agricultural Experiment Station, isolated Streptomycin from a soil organism, *Streptomyces griseus.* This antibiotic was found to be active against a wide array of bacterial diseases of both humans and livestock. The most significant is the tuberculosis organism—a world-wide plague which has scourged mankind and man's domestic animals for centuries.

Later Waksman and his co-workers, in 1949, isolated a group of three antibiotics, again from a related soil mold—*Streptomyces fradiae,* which he named the Neomycins. These also revealed activity against certain skin diseases of humans and livestock.

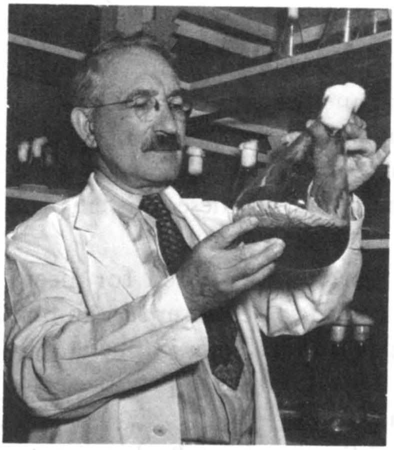
Benjamin Duggar, in 1948, after 40 years of research and teaching at the experiment stations in Missouri and Wisconsin, discovered with his co-workers at the Lederle Laboratories of the American Cyanamid Company the first of what became a series of extraordinarily effective antibiotics for both human and veterinary medicine—chlortetracycline (Aureomycin®)—from the soil mold *Streptomyces aureofaciens,* a yellow pigmented fungus.

Interestingly, the sample of soil from which Duggar isolated this particular mold came from the Missouri Agricultural Experiment Station.

The next discovery was oxytetracycline (*Terramycin*®), found by Finlay and associates at Pfizer Inc. Next came tetracycline (*Achromycin*®), developed first by Boothe and co-workers at Lederle Labs in 1953 by chemical modification of chlortetracycline, and later in 1959 by isolation from another soil mold by Heinesmann and associates at Bristol Labs. Inc. Finally, demethylchortetracycline (*Declomycin*®) was prepared by McCormick and co-workers at the Lederle Labs in 1957, again chemically from chlortetracycline.

Of these four tetracycline antibiotics, chloretetracycline and oxytetracycline have become most generally used in veterinary medicine and farm livestock, although tetracycline also is gaining increased usage. They all possess a broad scope of activity against many important diseases which induce skin, intestinal or general systemic infections.

Because of their stability in formulations, their breadth of spectrum, their activity throughout the body systems of animals,



Selman Waksman observing growth culture of *actinomycetes,* a major soil organism first identified by him in New Jersey in the early 1940's.

and their extraordinarily wide margin of safety, these tetracycline antibiotics quickly gained favor among the veterinarians and became the treatment of choice for a wide range of acute and chronic disease problems in livestock production.

In the ensuing years a number of other antibiotics have been discovered and developed for specific and various applications in agriculture.

High Quality Meats

During the 1940's a sharp rise in the general income of Americans created an increased demand for high quality meats in our diet.

Intensive research at many experiment stations had revealed the nutrient components essential for animal diets and how these could be combined and fed to achieve rapid growth and efficient production. Essential vitamins, minerals and certain amino acids (the building blocks of all proteins) were identified as to the kinds, the right quantities, and the best combination needed for the various stages of growth and product formation, as in milk, eggs, and meat. This was worked out for chickens, turkeys, pigs, sheep, beef and dairy cattle.

There was, however, one exception—an unknown growth and reproduction factor found in animal protein, but not in plant protein. This factor was required by all single stomach animals, such as the rat, dog, chicken, turkey, and pig but not the multi-stomach animals or ruminants, such as sheep and cattle. Apparently, then, ruminants were capable of producing their own "animal protein factor" (APF). It also had been shown in New Zealand and Australia that multi-stomach animals did, however,

require vegetation grown on soils containing the metal cobalt.

All single stomach livestock had, therefore, to be fed a source of APF or they would rapidly become anemic and their reproduction would fail. Such animal protein sources were supplied from meat scrap, fish meal, and byproducts of the dairy industry. As consumer demand for meat rose, the need for these animal protein byproducts soared.

Through the 1940's an intensive search was pressed for alternate, cheaper sources of APF. It was found to be present in animal manures, even in processed municipal sludge. This implied APF was actually not an *animal* protein factor but was produced by various "bugs" living in the intestinal tract.

Then Mary Shorb of the Maryland Station found a bacterium (*Lactobacillus lactis*) which also required APF to grow, and thus provided a rapid laboratory screening and assay tool to look for possible APF sources. The search quickly accelerated into a race.

Coincident with this research but quite independently, medical researchers for years had been seeking a dietary control for pernicious anemia, an often fatal disease in humans in which the body is incapable of making sufficient blood. The search had been narrowed down to unknown components present in animal livers (for example, beef and pork livers), and injectable liver extracts from these sources had been prepared to aid in controlling this fatal disease.

In 1948 all the various lines of investigation suddenly coalesced, when a dark red crystalline substance was isolated from animal livers and found to contain the metal cobalt. The compound was named "cyanocobalamine" or vitamin B_{12}, and was quickly identified as both the anti-pernicious-anemia factor for humans and the animal protein factor (APF) for single stomach livestock.

Now it was clear why ruminants did not require APF in their diets: the numerous "bugs" in their rumens could make it provided that cobalt was present in their forage.

This Vitamin B_{12}, an extraordinary compound, is active biologically at a few parts per billion in animals and man.

With the discovery of vitamin B_{12}, it became feasible to raise swine and poultry exclusively on plant protein diets—corn and soya plus minerals and vitamins. The search then began for cheap available sources of vitamin B_{12} for the feed trade. As it had been found to be fermented by various "bugs" (microflora), could the

fermentation residues from the production of antibiotics from molds be a source?

56 Percent Better Growth

Jukes and co-workers at Lederle Laboratories assayed the residues of chlortetracycline (Aureomycin®) fermentation. Vitamin B_{12} was indeed found to be present in the discarded cake. When a liver extract (vitamin B_{12}) supplement was fed to chicks on a vegetable diet, they grew 19 per cent more in 25 days than the controls. While on the antibiotic residue containing vitamin B_{12}, they grew 56 per cent better than the controls, giving an added growth of 37 per cent more on the fermented residue than from vitamin B_{12} alone.

The experiment was repeated, and again an increase of 36 per cent over that directly attributable to vitamin B_{12} alone was observed.

From what did this increased growth arise? Although the fermentation had been extracted for the antibiotic, it was found that about two grams of the chlortetracycline still remained in each pound of dried fermentation residue.

A few quick experiments on purified diets soon established beyond dispute that the antibiotic was indeed the factor which had induced the extraordinary increased growth.

Field trials immediately were initiated on chickens, turkeys, pigs, calves and sheep at experiment stations all over the United States, Canada and later in several European countries. The gathered results were even more spectacular than those first observed in the relatively hygienic laboratory animal rooms.

It seemed that the more exposed the test animals were to stress, adverse climate, and disease the greater became the improvement in growth, livability and feed conversion induced by the antibiotic in their diet.

Experiment station researchers began to test other antibiotics besides chlortetracycline—such as oxytetracycline, penicillin, streptomycin and bacitracin, and later erythromycin and tylosin—at low levels (2 to 10 grams per ton) in the rations of livestock, particularly of young rapidly growing animals.

Some differences were observed in the gains over controls for the various species of animals tested, and under the wide range of conditions tested. But in general a significant promotion in growth and feed conversion was reported.

Within two years of the initial laboratory discovery, a large number of livestock in the United States and Canada were being fed antibiotic supplements at least during the early stages of growth. Unexplained questions that remained however were: What precisely is the role of antibiotics in growth promotion of young animals? And what makes it work?

Even today, after 25 years, scientists cannot completely answer these questions.

For many years nutritionists and physiologists believed that intestinal "bugs" of divers species were essential for adequate diet digestion among all animals, including humans. Although it had long been established that such a joint relationship is essential for multi-stomach animals such as cattle, sheep and goats, doubts remained as to whether single-stomach animals (pigs, dogs, cats, rats, birds, etc.) and humans really did require such an intestinal population of helpful little creatures for their growth, maintenance and reproduction.

Early experiments designed to prove that certain intestinal organisms were in fact essential—by feeding known bacterial killers, such as sulfa drugs, to rats—produced uncertain results. For in some instances, the treated animals grew more rapidly and appeared healthier than the untreated controls.

In any case the concept of feeding livestock a suppressor of its intestinal "bugs", except in cases of known identifiable disease, was not encouraged for general farm livestock. It was in fact seriously frowned upon by some veterinarians.

Debate Rages

The sudden popularity of the practice of feeding antibiotics understandably initiated intensive debate among animal scientists. This was particularly the case at the time as there was really no reasonable, logical rationale to do so, other than the very practical justification that it worked, it promoted growth, it improved appearance, it reduced early mortality and morbidity (disease), and it returned to the grower a substantial savings.

That economic advantage quickly found its way into consumer markets as prices declined and quality improved. Consequently demand rose sharply, particularly for broilers, frying chickens, and turkeys.

But the question of mechanisms of action remained unanswered. Then workers both in England and the United States independently made an astonishingly but really quite reasonable

discovery. Rats, mice and chicks (and later, also, pigs), when grown under absolute sterile conditions, did not show the growth effect when fed such antibiotic supplements. The obvious implication was that this occurred due to the suppression of injurious or at least deleterious intestinal organisms.

Actually, earlier experiments had shown that germ-free animals grew as much as 50 per cent more rapidly than "controls" held in conventional quarters where normal "bug" populations were invariably present.

The mechanism of the antibiotic growth effect was then, at least in part, due to reduction of undesirable organisms. This also explains the abundant evidence from many stations which showed that thanks to low level diet supplementation with antibiotics, the animal could get more mileage out of its ration.

Many field trails revealed that among young rapidly growing, highly susceptible animals, antibiotics significantly reduced such diseases as scours in young calves, dysentery in baby pigs, toxic enteritis in lambs, and "mushy chick" disease in newly hatched chicks.

It was observed, however, that the beneficial effects of low level (2 to 10 grams per ton) feeding of antibiotics tended to wane as the animal grew, though often the initial advantage could still be noted at market.

At first it was concluded that the harmful bugs had become resistant, and therefore the efficacy of the antibiotic was dissipated. This was, in fact, to be expected. However, it was not the case. For new young animals set out in uncleaned quarters, previously occupied, and fed the low levels of antibiotics promptly revealed the customary growth effect.

It was finally recognized that all young animals consume much larger feed intakes per unit of body weight than do older animals. Thus if the antibiotic were to be increased in the diet so that the antibiotic intake per unit of body weight remained virtually constant, as the animal grew, then its effect would continue to be exerted until the animal went to market.

Laboratory and field trials again were set up at experiment stations in various states, in Canada and in England, and levels of antibiotics were fed from 10 to 400 grams per ton at both continuous constant levels and at rates that increased as the test animals grew.

Those antibiotics which are readily absorbed from the intestines (for example, the tetracyclines) yielded spectacular results. Not

Researchers have found that lambs can be removed from their mothers soon after birth and successfully reared on liquid milk replacer diets that include antibiotics.

only were the acute diseases prevented, but also those low grade infections usually present in massed flocks and herds which previously had been an expected sequel to the various unavoidable stress to which all livestock is exposed (vaccinations, dehorning, debeaking, sudden heat or cold spells, wet litter, transportation, etc.).

Thus outbreaks of such "stress" diseases as shipping fever, foot

rot, chronic respiratory disease and various forms of enteritis were effectively quelled.

With these developments, substantial changes in management procedures evolved.

Before the general use of antibiotics in feeds and drinking water, animal groups had been kept small. This was because it had long been recognized that large groups of massed livestock inevitably encourage outbreaks of serious disease which generate excessive mortality and costly sickness among the survivors. Lost feed conversion and increased days to market could readily become ruinous.

Broiler Flocks of 40,000

With the introduction of antibiotic feed supplements fed to prevent the outbreak of such diseases, more animals could be housed safely together and more groups could be held simultaneously on the same farm or feed lot. Flocks of broilers were promptly increased, from 3,000 to 5,000 to upwards of 20,000 to 40,000 within the same house. Cattle on feed lots were increased from a few hundred to tens of thousands.

The economics in labor, overhead, and "turn around" time substantially reduced the cost of production, which quickly became reflected in reduced prices to the consumer.

To manage such immense groups of livestock, continuous disease prevention rather than treatment became mandatory. Antibiotics, along with vaccination procedures to immunize livestock against virulent virus diseases, rendered such mass production of livestock practicable and economically sound. This also was the case with other feed medicaments such as coccidiostats to prevent coccidiosis in poultry, and anthelmintics to prevent worm and parasite infestations.

To attempt to treat diseased chickens individually from a flock of 25,000 was obviously quite impracticable. At times it becomes necessary to provide a treatment to control a sudden outbreak of disease, and this generally is attempted by applying the treatment either in the feed or water, or, occasionally, through the air with aerosolized medicine.

However, among such massed animals those which need treatment the most get the least. Those which need it the least get the most, due to the inevitable inability of sick animals to stand up to the competition at the feeders and waterers.

With larger animals such as pigs, sheep and cattle, it is possible

to isolate the sick animals. However, this requires special facilities, considerable labor and professional help. In any case, the disease probably has started already in the apparently healthy animals, which in turn also will require individual treatment.

The grower is fortunate under such dire circumstances if he can retrieve his investment, without profit.

In addition, meat inspection regulations at the dressing and packing plants have become increasingly stringent in recent years. This is largely because the introduction of preventative antibiotic and other medicament feeding of livestock has shown how clean animals can be raised virtually free of disease.

These increased standards, directed primarily at maintaining public health, make it impossible for the producer of livestock intended for marketable meat to remain in business unless he can proceed under a production program first of massed flocks or herds, and second of almost total disease prevention.

If either of these procedures are withdrawn, the predictable result will be a substantial decline in overall meat production efficiency and a sharp and ruinous rise in meat prices to the consumer.

The mechanism of the antibiotic growth effect is, then, the suppression of deleterious micro-organisms. Some of these exert only competition for nutrients. Others coincidentally produce poisons that impair growth efficiency. Still others elicit low grade or chronic disease that can under certain unfavorable conditions burst into fierce disease. And, finally, a fourth group can readily invade massed animal groups and induce serious mortality.

In a sense all animals and, presumably, living things all suffer from infective disease all the time. Those animals fed antibiotics continuously in their diet merely sustain a much lower level of disease from a reduced array of organisms. They therefore respond better in terms of overall growth efficiency.

Resistance Question Raised

Since the use of antibiotics in farm livestock feeding began, the question has been raised repeatedly as to possible development of bacterial resistance to the particular antibiotics used. This was fully anticipated. Monitoring studies were initiated at several stations to determine whether it was actually occurring and, if so, whether it would indicate the ultimate decline of the antibiotic effect.

By the middle of the 1950's such a decline was observed at

some stations where antibiotic feeding studies had been underway for several years. The curious fact developed, however, that the reduction in the observed antibiotic growth effect was not due to slower growth of the treated animals but to a rise in the growth rate of the untreated controls.

Apparently the continuous use of antibiotic-supplemented feeds in the surroundings had reduced the overall level of unfavorable germs to the point that even the untreated animals showed improved growth. However, when all antibiotics were removed from these particular environments, in a relatively short time the overall growth efficiency declined and the antibiotic growth effect could be demonstrated once again.

A survey of the use of antibiotics in livestock feeding reveals that the effect of growth efficiency has been sustained in all areas studied for over 20 years.

The feeding of antibiotics to livestock, at least at registered levels, does not sterilize the intestines or the bodies of the recipient animals. Therefore a considerable number of bugs of many species survive. These obviously are inherently "resistant" to the antibiotic used at the dose level fed.

Yet they do not constitute a threat or hazard either to the particular animal species, to other species within the same environment, to humans who attend them, to those who slaughter, dress or process the meat, or to the consumer of the edible product.

It must be obvious that if the efficacy of antibiotic feeding to livestock had really subsided to the point where it had become ineffective due to resistant organisms, the industry—pressed, as it is with mounting costs—would swiftly abandon the practice.

In 1960 a new discovery, made first in Japan and later confirmed in Europe and the United States, created a fresh concept and concern over the use of antibiotics in the feed of farm animals.

It had been noted that certain strains of a disease organism causing dysentery in man (*Shigella*) had developed considerable resistance to virtually all drugs previously employed for its treatment, including several antibiotics. This resistance could not be accounted for by the normal course of selection and evolution.

The discovery was made that certain strains of common intestinal bacteria, which themselves usually are not serious disease inducers, can "infect" their multiple drug resistance characteristics into drug-susceptible organisms that induce intestinal dis-

ease, simultaneously rendering them also resistant to the several drugs.

These "infective" drug-resistant bacteria apparently possess a Resistant Transfer Factor (RTF) which enables them to transfer their multiple drug resistance even to essentially unrelated species. That astonishing property instantly excited the interest of many scientists, including of course physicians, veterinarians, nutritionists, and livestock researchers.

Review by the British

In England it generated considerable excitement, and a Committee was authorized by Parliament—the Swann Committee—to review the entire subject with special reference to the feeding of antibiotics to livestock.

It was thought that if such a transfer of multiple drug resistance should occur among livestock, with otherwise drug-sensitive strains of disease organisms which also could infect humans, then there was the possibility that a serious epidemic of disease could develop among the public that might not be controlled with any available drug or antibiotic. This was admittedly a horrifying prospect, if it were reasonably likely to occur.

That such a nightmare is unlikely is attested to by the fact that over the past 24 years in the United States and Canada literally tens of billions of head of livestock were fed a wide array of antibiotic and other drugs over a broad range of doses—without a single medically annotated incident of such a multiple-drug-resistant disease moving from any kind of livestock into the human population and creating an uncontrollable epidemic.

The incident which triggered the concern in England did not in fact concern the everyday feeding of antibiotics to livestock. For the alleged original source of the resistant disease (*Salmonella typhimurium*) came from a group of clearly mishandled new born calves not fed colostrum before shipping. The calves had received a "shotgun" injection of several drugs.

The disease became rampant among the calves, killing half of them, and allegedly reaching a children's hospital, where six infant fatalities occurred before the outbreak was brought under control.

Actually, of course, the drug of choice for treatment of this particular infection in humans (*Salmonella*) is not one of the tetracycline antibiotics. They are largely ineffective against this organism at normal feeding levels, and therefore would not have

exerted any significant selective effect. The best antibiotic to have employed would have been chloramphenicol, which is not fed to farm livestock.

Succeeding laboratory investigations did, however, reveal that the particular strain of the intestinal organism involved (*E. coli* phage type 29) did possess the inherent resistance transfer factor (RTF) and was indeed resistant to several commonly fed antibiotics. In lab cultures it could readily transfer to the otherwise antibiotic-sensitive organism (Salmonella), rendering it also drug resistant.

The interpretation then was made that such resistant organisms in humans are derived from antibiotic-fed livestock. And the final recommendations of the Swann Report were that all such antibiotic feeding of livestock should be suspended in the United Kingdom except under the direct supervision of a veterinarian. After public and Parliamentary debate which extended for nearly two years, the ordinance was implemented.

Although the use of antibiotics in animal feeds in the United Kingdom is now more closely controlled than previously, they continue to be fed under professional supervision, and no further serious human disease problems have been reported.

In the United States the feeding of antibiotics is presently under review. But as no hazards to public health have been demonstrated, the practice is not as yet restricted, beyond the specifications of use required in the Federal registration of every antibiotic and drug.

In the meantime further research has uncovered several interesting and reassuring facts:

- Transfer of drug resistance between differing species of bacteria occurs much more readily and frequently under artificial laboratory culture conditions than it does in the intestines of living animals. Whether the rapid transfer observed in the laboratory is largely an artificial effect, or whether the competition within the living intestines tends to prevent the transfer, is not yet clearly defined. However, it has been shown to occur in the living intestines, although rather infrequently
- It has also been shown that cultures of bacteria into which resistance has become transferred can quite readily lose it again. Perhaps this also occurs even more rapidly within the living intestine. Certainly the evidence reveals that cultures with transferred resistance grow less vigorously after the transfer than they did

before. This would render them less capable of survival as they become "overgrown"

- Cultures into which drug resistance has been transferred are often, though not invariably, less capable of inducing disease in the host than were the previous drug-susceptible cultures. They often differ in visible shape and appearance and generally show a considerably reduced rate of growth

The potential evolution of pests of any kind that are resistant to control procedures—whether bacteria, fungi, internal parasites or insects—is of course a constant concern to all producers of crops and livestock. On balance, however, the threat falls far short of the very certain losses that invariably occur when no controls at all are employed against such pests. The only question of merit is the one of the risk : benefit ratio to man.

In the use of antibiotics in agriculture, primarily for livestock production, the risk : benefit ratio weighs so heavily in favor of benefit that there should really be little dispute.

It has been estimated that withdrawal of the use of antibiotics from livestock production would promptly raise the cost of meat and animal products by at least $1 billion a year at the consumer level.

Such an inordinate and really quite unnecessary increase in food costs would incite considerable public reaction both in the United States and in many foreign countries.

On the other hand, the proposed risks from the continued use of antibiotics in agriculture are in fact essentially unsupported by experimental evidence, public health considerations, or practical field experience extending, by now, for over 20 years.

Natural Enemies Used to Fight Insect Ravages

By Paul Gough

For centuries farmers have depended on nature and luck to protect their crops from insect attack. Often crops were lost or extensively damaged, but parasites, predators, disease or starvation usually brought such insect pests under eventual control.

In Utah in the 1850s, a three-year-long plague of Mormon crickets was brought to an end by sea gulls—which saved the crops of the early settlers from almost certain destruction.

A more recent demonstration of natural control occurred in Connecticut during the early 1970s. For several years elm spanworms defoliated thousands of acres of trees in forests and backyards until nature again came to the rescue.

Frustrated residents had turned to insecticides to help them recover their yards from the caterpillars and controversy raged over public spraying programs. At the height of the infestation, entomologists from the Connecticut Agricultural Experiment Station discovered tiny wasp parasites quietly destroying spanworm eggs in the southwestern part of the state.

The wasps, which do not sting people, lay their eggs inside the eggs of spanworms. This provides the parasites with nourishment but is fatal to the developing caterpillars. In some areas the entomologists found the wasps had destroyed all of the eggs. Based on this information, they were able to predict that an end to the infestation was near.

Within two years spanworms were almost completely absent in every section of the state where they had previously been present in large numbers.

This Connecticut experience shows that natural enemies can destroy large numbers of pest insects in a relatively short period of time. But such relief often comes too late to suit people

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bothered by pests such as the spanworms or to suit farmers whose crops are threatened. Under these circumstances other methods of insect control are sought.

A new era of pest control began during World War II when DDT was first used to control disease-carrying insects. This chemical was effective against a large number of pest species, was easy to use, was inexpensive, and was quite dependable. But scientists quickly recognized that insects were able to build resistance to DDT and other chemical insecticides.

Chemical insecticides also must be applied repeatedly to continue to keep pests under control, and they often have killed beneficial insects such as bees or natural enemies of the pests. Because of these and other problems with insecticides, the trend in pest control is now toward development of controls that closely parallel the actions of nature.

Biological control by imported parasites was used by the California Agricultural Experiment Station to bring under control the olive scale, a pest of olives, plums, apricots, other smooth-skinned fruits and of 200 different hosts including ornamental trees.

Since the scale was native to Asia and the Middle East, the logical place to look for natural enemies was in these areas. This importation technique was successfully demonstrated in California in the late 1880's when the U. S. Department of Agriculture (USDA) imported vedalia beetles from Australia to control the cottony-cushion scale which threatened the state's citrus crop.

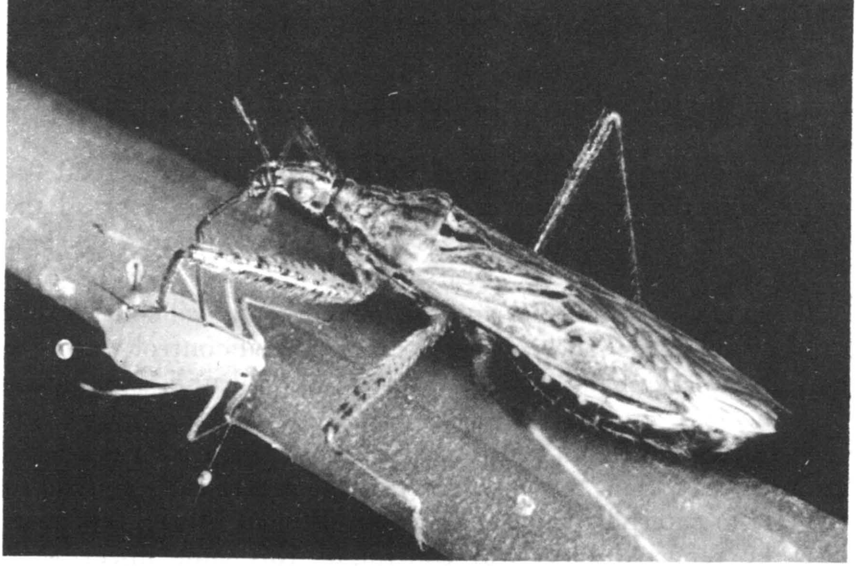
Imported Wasp Weighs In

The California scientists sent overseas to search for natural enemies found that the olive scale was only a minor problem in most areas. This contrasted with its serious pest status in California where no natural enemies were established.

A parasitic wasp, *Aphytis maculicornis*, collected in Iran, was brought to California as a result of this effort. The parasite appeared to have great promise as a biological control because it had six generations per year while the olive scale had only two generations.

Since both insects laid about the same number of eggs, the parasite could easily overcome the reproductive capacity of the olive scale under the proper circumstances. Millions of the wasps were released, and good control was achieved in some areas.

But in the Central Valley where summers were hot and dry,



A team of scientists from Ohio, New York, and Massachusetts discovered an early warning system in aphids based on a chemical repellant (alarm pheromone). When an aphid is attacked by an insect predator as in this photo, it secretes a tiny droplet containing the pheromone. When the droplet evaporates it warns other aphids of impending danger. Ohio researchers are studying the possibility of treating plants with synthesized alarm pheromones to deter aphid infestation.

Aphytis was not fully effective. Because of the variable results, many growers did not adopt the parasite as a biological control.

Several years later, while California scientists were looking for natural enemies of another insect, they found two more parasites of the olive scale in Pakistan. One of these was found to be well established four years after it was introduced in California.

Although *Aphytis* working alone could not control the olive scale sufficiently to be an acceptable means of reducing fruit damage, its activity was supplemented by that of the newcomer and together they produced effective biological control.

Parasites do not always have to be collected from overseas. Some agricultural pests originate in other areas of the country and become established because they manage to overcome natural geographical barriers or are carried into new places by the activities of man.

Skeletonizer Scratched

To find parasites of the grape leaf skeletonizer, California scientists only had to go to Arizona. Quite by accident a virus disease was brought into the state along with some parasite mate-

rial, and this turned out to be the necessary element for biological control.

Although the parasites helped, the virus received the credit for controlling the grape leaf skeletonizer. The parasites spread the virus in the grape-growing areas of the state, bringing the pest under control within three years in most places.

Insect diseases thus offer another area of biological control that can be explored. Pioneering work in microbial control was done by Edward Steinhaus at the California Agricultural Experiment Station.

Steinhaus was the first American scientist to use a virus against an insect pest. This was in 1948 when he successfully controlled the alfalfa caterpillar with a polyhedrosis virus. And a few years later he reported successful control of this same insect with *Bacillus thuringiensis*, a bacterial agent grown on nutrient agar.

Bt is now registered for numerous caterpillar pests including those that affect such diverse plants as lettuce and shade trees. *Bt* does not harm most beneficial insects so it is compatible with most biological control efforts.

The specificity of most insect pathogens makes them desirable from a biological control point of view.

Breeding of insect-resistant plants has produced some outstanding results and shows great promise for the future.

Greenhouse studies of Hessian fly resistance in wheat were begun at the Kansas Agricultural Experiment Station in 1914, and yielded a resistant variety that was released in 1931. These and other studies have produced at least 25 other varieties of wheat resistant to the Hessian fly.

The efforts to produce Hessian fly resistant wheat have been so successful that some State Experiment Stations will no longer release a new variety of wheat unless it is resistant to the fly.

A variety resistant to the wheat stem sawfly was developed in Canada during World War II, and the Montana and Arizona Agricultural Experiment Stations worked together to produce large quantities of seed for planting in Montana.

Only one bushel of wheat was available, but the combined efforts of the two states turned this single bushel into 60,000 bushels. That feat was accomplished by planting the available seed in Arizona in the fall and in Montana in the spring over a period of several years.

This variety, appropriately called Rescue, reduced sawfly damage to less than 10 percent compared to as much as 90 per-

USDA and California scientists cooperated in developing a muskmelon resistant to insects and diseases. Above, cages containing aphids are placed on melon leaves in test for insect resistance. Inset, resistant hybrid melon bred from India and U.S. commercial melons.

cent in non-resistant varieties. Rescue, however, was not resistant to rust, so another variety had to be developed for eastern Montana and North Dakota where rust and the sawfly were serious problems.

Fortuna, the first rust and sawfly resistant wheat, was released to farmers in 1966 as a result of research conducted by USDA and the North Dakota Agricultural Experiment Station.

250,000 Plants Screened

Development of insect-resistant plant varieties is no easy task for plant breeders. For example, during the effort to develop an

alfalfa variety that would resist the spotted alfalfa aphid, the Kansas Agricultural Experiment Station screened 250,000 plants of the same variety.

Only about one percent of the plants survived when they were exposed to aphids. After these plants grew to a height of at least six inches, they were again exposed to aphids.

Following this, only 101 plants remained for the further laboratory and field tests which were required to produce the alfalfa-resistant variety that was ultimately released to farmers in Kansas.

Despite the great effort involved in screening of plants to select only those that seem to be the most promising, resistant crops offer an attractive means of control because farmers can reduce insect damage to their crops merely by purchasing the proper resistant seed.

Although resistant crops provide insect control, the gain may only be temporary. Just as the plants can be manipulated to produce insect resistance, the insects can adapt to the new varieties and in time may again become a pest.

The results of the past, although encouraging, seem to indicate that biological controls will not be developed for all significant pests of agricultural crops. Instead, a combination of techniques will be required.

Farmers may use insect-resistant crops even if they do not present total protection, and supplement this control with pesticides, parasites, predators, and diseases as necessary.

The advantage of biological methods of insect control is that they usually leave other natural controls intact. This allows the pest to be reduced in numbers without destroying the forces that normally help keep it under some control.

Biological methods are often less expensive than chemical controls. They generally are effective over a longer period of time, and are non-toxic to man and most other organisms. This allows maximum pest control with a minimum amount of effort, expense, and environmental disruption.

Since effective insect control must be achieved to continue the steady flow of food to the nation's tables at a reasonable cost to both farmers and consumers, experiment station researchers in many areas of the country continue to look for ways to exploit nature to protect plants and people.

The Fire Brigade Stops A Raging Corn Epidemic

By James G. Horsfall

Columbus sailed west seeking spices to flavor and preserve his unrefrigerated food. He found no spices, but he discovered corn, an incredible crop that fed his country well and required no refrigeration.

It was a staple of the New World then, and now is a worldwide staple. It is the third most important food producer in the world, following closely after wheat and rice. We feed it to animals and get back steaks, hams, and hamburgers. We drink bourbon made from the grain and smoke pipes made from the cobs. We eat it directly as corn bread, corn flakes, corn pone, johnnycake, hush puppies, grits, and hominy.

No wonder the nation was worried in 1970 when an epidemic swept like fire through the corn of the country and into the pages of the popular press. Had that fire gotten out of hand, it could have burned big holes in the complex web of the nation's food system.

The disease killed off 15 percent of the Nation's corn that year, 100 percent in some fields. Fifteen percent standing alone is a dry statistic, but it amounted to 1.02 billion bushels of corn. Had it been fed to cattle it would have produced 7.7 billion steaks at one pound each, or over 30 billion quarter-pound hamburgers. This is easily three times the total sales of a major hamburger chain whose sales statistics are prominently displayed.

The epidemic first appeared near Miami in January, 1970. It swept rapidly northward with the greening wave of corn all the way to Minnesota and Maine where it faded out in early fall.

It produced lesions on the leaves until they died and shriveled. It then attacked the ears, punching its way through the husks to the grain. Come fall, the mechanical corn pickers were

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enveloped in a black miasmic cloud of spores of *Helminthosporium maydis*. No disease ever before had been so destructive to corn.

To set the perspective let us examine a few other classic epidemics of history.

The Great Irish Famine

Two of the worst famines of all time were due to epidemics of plant disease. The most famous in the western world was the great Irish famine, during the 1840's. The dreaded late blight disease destroyed potato crops of the Irish for several years running.

Since there were no firefighters then, this fire burned for several years. Some 1.5 million people died.

Next came the equally devastating Bengal famine of 1943 in the eastern hemisphere, a century later. The Bengal rice crop had been destroyed by a fungus the previous year. According to a recent analysis of that frightful event, two million people died and the streets and highways were littered with their bodies.

Effects of both of these famines were greatly intensified as a result of overpopulation, political troubles, and poor transportation.

We in the United States could give up corn worth 30 billion hamburgers in 1970 without creating a famine because we could substitute wheat or other crops, and we have a highly sophisticated transport system and no severe overpopulation.

Oldsters among us will remember the wheatless days in our country in 1917. This followed a severe epidemic of wheat rust disease in 1916 that consumed two million bushels of wheat in the United States and a million in Canada. Nobody starved, since we substituted corn bread for wheat bread.

The world has seen other destructive epidemics. Pests almost wiped out the French wine industry three times in the nineteenth century. Coffee rust broke the Oriental Bank of Ceylon in the 1880's and recently has invaded Brazil, where the impact is in the hands of the gods.

Before we turn to the corn blight epidemic, let's look briefly at hybrid corn itself because without hybrid corn, I would have no firefighter story. (The hybrid corn story itself is dealt with much more fully in an earlier chapter of this Yearbook.)

Corn is an exceedingly plastic organism. The great principle at the base of hybrid corn has enabled researchers all over America

to knead it and mold it into a wide variety of forms: tall corn, dwarf corn, sweet corn, silage corn, popcorn, corn for the hot tropics, corn for the cool north, for humid climates, corn for dry areas.

The yield has been raised, raised again, and yet again. It has tripled in 30 years. And the end is not in sight. It stands as a great tribute to agricultural research in America. Thus it is fitting to discuss it in a Yearbook marking the centennial of the experiment stations in America. Hundreds of researchers have contributed to the corn saga.

A few iconoclasts in the Nation hold that science and technology are problems for the Nation, not solutions to problems. To them, science and technology gave us the automobile and adolescents are killed. They overlook that science and technology also gave us penicillin and adolescents are saved. My daughter was one.

Science and technology do sometimes develop side effects. Some adolescents are allergic to penicillin. These side effects must be dealt with as they arise. In one sense the corn blight epidemic was a side effect of science and technology. But it was science and technology that came to the rescue and put out the fire. As a result the Nation still enjoys the benefit of hybrid corn technology without the side effect.

Questions flew hot and heavy in 1970. What happened? Where did technology go awry? Why didn't we see it coming?

Let's examine these questions. First, what happened? We will deal with this question by examining the anatomy of the epidemic.

Anatomy of an Epidemic

The fire was no case of arson. No foreign people brought in a virulent parasite and turned it loose in our corn. We simply left the oily rags in the basement and they caught fire. We now know what we should have done. We didn't see it in time.

It took us about six decades to set the stage for the epidemic. In 1907 Shull of the Carnegie Institution invented the pure line method of breeding corn. This became the base for hybrid corn.

Corn being open pollinated was a potpourri of genes. There were genes for yellow corn, white corn, red corn, flint corn, weaklings, dwarfs, giants—even genes for corn that grew along the ground like a vine.

Shull eliminated the variability by inbreeding, so that he ended with pure lines. This had as important an impact on corn breeding as "chemically pure" compounds had in the chemical industry.

Shull and his scientific sons that followed him produced pure lines for varieties, all conditions, and all areas.

Ten years after Shull, Jones at the Connecticut Station took four pure lines to produce his famed four way cross. This is somewhat facetiously called the "double cross." The first year Jones crossed line A with line B and line C with line D. The second year he crossed AB and CD. And thus he invented a method for making inventions.

As a result anyone, anywhere, could inbreed his own pure lines and cross the best to give him the proper corn for his conditions. That is how the breeders kneaded corn.

Jones' double cross method with pure lines was too complex for a farmer to use, however. No farmer could keep the lines pure and make all the controlled crosses.

Jones persuaded a local Connecticut farmer to set up a hybrid corn business—the very first one. But it took a Henry Wallace in Iowa to make it go commercially. And thus came into being the hybrid corn companies.

The Seventh Row

In practice, the corn companies grow six rows of the AB side of the cross and a single row of the CD side. Originally they hired thousands of high school students to go down the six rows and pull out the tassels and thus destroy the pollen. This left the seventh row to produce all the pollen. The pollen from the seventh row pollinates the others, and hybrids are produced for sale.

By 1931 we were 24 years along the road to the epidemic. In that year Rhoades discovered a strain of corn with sterile pollen. Forward looking breeders thought, "Ah, hah, we could use this in the female six rows and avoid all that expensive detasseling."

Alas and alack, it did not work because Rhoades' pollen sterility factor was inherited through the cytoplasm, not through the genes. Thus, it was inherited in the female line. If the farmer were to plant seed so produced, his crop would also be sterile. He would then sell only cobs. Rhoades' strain, not finding a use, was lost. The epidemic was delayed.

In 1945, we were 38 years along. That year Mangelsdorf and

Three stalwarts in hybrid corn technology: left to right, D. F. Jones, Henry A. Wallace, and Paul Mangelsdorf.

Rogers in Texas discovered another male sterile line, which eventually became known as the Texas male sterile line. Here was another chance to get rid of detasseling, but this sterility also descended in the female line and, if used, would sterilize the farmer's crop. Nevertheless, the strain was saved.

Things speeded up a little. By 1948 two thirds of the time had passed by. Jones, of double cross fame, said to himself in 1948 that there are genes for everything—there must be a gene that would correct the male sterility. He searched his vast collection of corn genes and discovered such a one which he dubbed the restorer gene.

Hybrid corn makers got the restorer gene from Jones and the Texas male sterile strain from Texas and incorporated both in their breeding lines. Success was on the way, but so was the epidemic.

Essentially all the corn varieties of the country, and abroad as well, were converted to the new process of making hybrid corn. The high school students lost their jobs. Hybrid corn now was produced on Texas male sterile cytoplasm. And thus nearly every corn plant in America came to be an identical twin with every other one in the sense that they both contained Texas male sterile cytoplasm.

The stage was set for the epidemic. Come 1970, a new actor walked on the stage and converted a pleasant drama into a near tragedy. The new actor, *Helminthosporium maydis*, is a tiny mold that had mutated from a second rate parasite of corn into a vicious killer.

A distressing question of 1970 was, "Why wasn't it foreseen?" For one thing we often say, "It can't happen here." The Cassandras who predicted the current energy shortage were ignored and then were asked, "Why didn't you tell us?"

Jones warned the corn fraternity in 1958, or 12 years before the epidemic. He wrote, "Genetically uniform pure line varieties are very productive and highly desirable when experimental conditions are favorable and the varieties are well protected from pests of all kinds. When these external factors are not favorable, the results can be disastrous due to some new virulent parasite."

Jones was dead by 1970, but the "virulent parasite" was not.

In 1958 Duvick, a distinguished commercial corn breeder, got worried. He tested Texas cytoplasm against *Helminthosporium maydis*. The results were negative.

Four years later in 1962, Mercado and Lantican in the Phillipines reported that Texas cytoplasm corn had been virulently attacked by *Helminthrosporium maydis*. They did not warn their fellow corn breeders of any impending epidemic, however.

Duvick got worried again in 1965. He checked again—still negative. He wrote the Phillipine result off as due to rainy tropical weather.

The warning flags were up, but it was hazy and they were hard to see. Although Duvick surely tried, he did not foresee a mutation in *Helminthosporium maydis*.

The Deadly Triangle

Let's have a look at the technical base of the epidemic. Three major conditions must come together simultaneously to generate an epidemic of disease. There must be a susceptible host, a virulent parasite, and favorable weather conditions—the magic triangle.

In most epidemics the parasite is an exotic. A few years ago we imported a virus from Asia and we had Hong Kong flu. We imported a fungus on Chinese chestnut nursery stock, and the ensuing epidemic wiped out our chestnut trees because they were susceptible.

In the corn blight epidemic we unwittingly built susceptibility into the host with Texas male sterile cytoplasm. The weather in 1970 was favorable from Miami to Minnesota. The question of the origin of the virulent strain of the fungus is a little obscure, but it was probably a local mutation of the fungus—a change in the genes of the fungus that made it virulent on Texas male sterile cytoplasm.

A mutation is a rare occurrence, once in a million, say. *Helminthosporium maydis* has been around in corn fields making a few lesions on leaves at least since Squanto taught the Pilgrims how to grow corn. Corn had always been resistant to it, so one leg of the magic triangle (a highly susceptible host) was missing.

It is probable that *Helminthosporium maydis* did produce from time to time a mutation which could have been virulent on Texas male sterile cytoplasm. But if it did, the mutation died out because there was no Texas cytoplasm to trap it.

When Texas cytoplasm did appear, we couldn't have done better had we deliberately tried to capture a mutation of the parasite that could attack it. We spread a net of Texas cytoplasm across the nation—indeed across the world. If a mutation of the fungus occurred anywhere, we had the Texas cytoplasm there to catch it. If no mutation occurred one year, we spread our net the next year and the next until we did catch one that appeared.

This, I emphasize, is the view of a Monday morning quarterback, but it does suggest ways of avoiding the mistake again.

The operative word in the concept we have been discussing is uniformity, a strong predisposing factor, which Texas cytoplasm provided. Uniformity is thus a *sine qua non* of epidemics. In the 1960's we had a bridge of uniformity northwest from Miami to Minnesota and northeast from Miami to Maine. There were no missing spans in the bridge. The fungus marched across the bridge and into the newspapers.

The potatoes in Ireland were uniform, too. The *Lumper* variety provided a bridge from Cork to Belfast just as the Texas male sterile corn provided a bridge of uniformity from Miami to Minnesota.

The highly susceptible chestnuts provided the same bridge of uniformity for the chestnut blight disease from Mt. Katahdin in Maine to Stone Mountain in Georgia. Likewise, the Marquis variety of wheat provided a neat bridge across the wheat belt for the rust disease in 1916.

Another important factor in epidemics is monoculture (single crop farming) which jams plants together. Farmers crowd corn plants in the field and they crowd the fields.

Mothers warn all children to stay out of crowds if diseases are around. Farmers can't keep their plants out of crowds.

Farmers know the hazards of monoculture, but it is an economic necessity for both farmers and consumers. One alternative to monoculture would be to return to a food gathering procedure

used by tribes 20,000 or 30,000 years ago. This option, of course, is impossible. Monoculture is the base of agriculture and agriculture is the base of modern society.

Science and technology, then, must provide solutions to the disease hazards of monoculture, and by and large they have. To drive an epidemic, the parasite must be virulent. In general, virulence comes in with an imported exotic or as a mutation. The potato blight fungus was imported from Latin America, the chestnut blight fungus from the Orient, and the corn blight presumably from a mutation.

Putting Out the Fire

In 1970 the scientists who were to quench the fire assembled from all over America, from the Agricultural Experiment Stations, from industry, and from the U.S. Department of Agriculture (USDA). Those concerned rose to a man, donned their firefighting hats, and put out the fire. Yes, it still smouldered in 1971 and a few wisps of smoke showed in 1972, but it was well under control during 1971.

What did they do? They debated long and late, but actually they had only three options, one for each leg of the magic triangle. They could not command nature to retract the mutation of the fungus that she had produced, and thereby break the parasite leg. They could do little to control the weather leg of the triangle. Thus, they could really only deal with the host leg of the triangle.

They knew the susceptibility was due to the Texas male sterile cytoplasm. They would, therefore, return to the use of old fashioned "normal" cytoplasm. In the winter of 1970–1971 they grew corn mostly anywhere warm enough to grow corn—Puerto Rico, Mexico, Argentina, Hawaii, and Australia.

They had to rehire all the high school students for detasseling. They sold the newly produced corn with normal cytoplasm in what they thought were the most susceptible places. In order to have enough seed for the other areas, they mixed the normal corn seed with Texas line seed and left the Texas corns to the northernmost areas of the country where the weather was less favorable to the disease.

Nature cooperated. She reduced the impact of the weather leg of the triangle. The weather was less favorable than in 1970. Altogether, the corn yield jumped back to normal in 1971 and the fire was essentially out.

Other Crops Vulnerable

The epidemic raises a serious question: How vulnerable are other crops? The answer is that they are indeed vulnerable, because of their uniformity. Uniformity of cotton varieties in some parts of California has been enforced by law, as has uniformity of wheat varieties in parts of Canada.

Farmers have insisted on uniformity of plant size, ear height, etc., for mechanical planting, weeding, harvesting. The market demands a uniform product. Our whole agricultural system is geared to uniformity and uniformity is geared to epidemics.

Herewith is listed uniformity of some of our crops in descending order:

Millet	100% in 3 varieties
Peas	96% in 2 varietal types
Snap beans	76% in 3 varieties
Potato	72% in 4 varieties
Wheat	50% in 9 varieties
Sugar beet	42% in 2 varieties

The Norin dwarfing gene in wheat is spread all over the globe, as is the Taichung dwarfing gene in rice. Every snap bean in America has the same gene for stringlessness.

No fungus has so far mutated to like any of these genes, but the operative phrase is *so far*. We hope never.

We suddenly learned that we had not done well in saving genes for our major crops. Fortunately, we still had the "normal" genes to combat the corn blight and we used them. But our gene pools for most crops are woefully looked after.

Yes, we have gene pools for some crops. The International

Taking infra-red photos from a "cherry picker" basket, a remote sensing researcher in Michigan works to identify the "signature" for several different conditions of corn. This makes it possible to identify the conditions, including corn blight, from high-altitude photos.

Rice Research Institute in the Philippines has a great collection of rice genes and CIMMYT, the wheat and corn institute in Mexico, has the same for wheat genes.

Most genes are preserved by individual geneticists and breeders, however. They are preserved by the firefighters themselves, not by society which needs them.

For instance, the opaque-2 gene for corn was collected by Jones and described and preserved by Singleton and others for nearly 50 years before it was found by Mertz and Nelson to be the gene for high lysine corn. It easily could have been lost. The nation is now hard at work to set up better gene pools. We will surely need them to put out some future fires.

Fighting Fires Abroad

We learned another important fact for fire fighting. We know most epidemic fires have been lighted by imported parasites. We could have listed others: Dutch elm disease, banana wilt, grape mildew, tobacco blue mold.

This shows beyond a doubt that we should fight fires abroad, before they move by some jet plane across the ocean to our crops. We said that the Filipinos first saw a devastating strain of *Helminthosporium maydis*. We should have sent our firefighters and our corn strains over there to learn the tools and methods needed, in case the blight ever hit here.

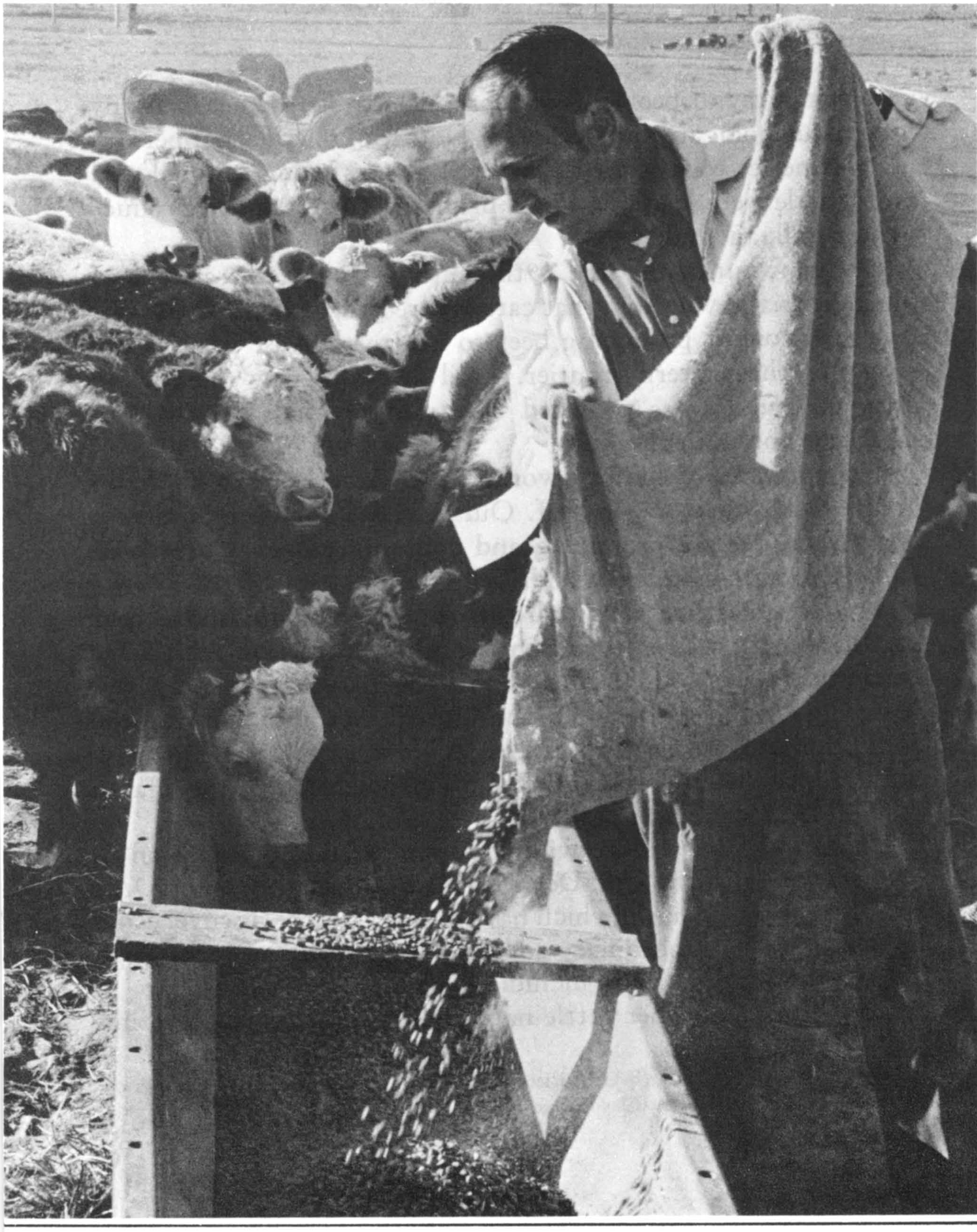
Perhaps the point of the story is that the Nation established and preserved a system of agricultural research in America that could be and was marshalled to fight the fire. Society set up the research system originally to serve agriculture, to make it more efficient so that the people would have sufficient quality and quantity in food and fiber.

The system succeeded so that for some 40 years between 1930 and 1970, the Nation could produce more food than it could eat. In 1933, at the bottom of the depression, there was considerable pressure to plow under every third production researcher along with the third row of crops and the third little pig.

The agricultural science effort did falter somewhat but it was kept in being, and proved its worth in 1970–1971.

All in all, the fire was an exciting episode in the life of the scientists in the experiment stations, USDA, and industry. It is a marvelous tribute to the wisdom of the men who set up the system a century ago, and to the wisdom of those who kept it going despite pressure to weaken or even dismantle it.

MEAT, MILK, FISH



Beef—From Trail Drives to America's Main Course

BY LARRY V. CUNDIFF

A vast array of beef cuts and products to fit the needs of any household are an accepted fact to grocery shoppers in America today, but this has not always been so. In colonial times cattle were scarce and used primarily for work and production of milk and hide.

It was not until the mid 19th century, during the advent of the industrial revolution, that cattle were propagated for the primary purpose of producing beef to utilize the vast prairies and ranges of the western frontier. Trail drives to new railroads in Missouri and Kansas provided for transportation of cattle to slaughter houses in the East.

The appetites of factory workers and Americans of all walks of life were whetted for beef. Our appetite for beef increased, until today we are producing and consuming over a fourth of all beef produced in the world.

At the same time that railroads were developing and a beef cattle industry was emerging in the West, legislation with a far reaching impact on agriculture and the nation's economy was passed in Congress. In 1862, the Morrill Act provided for the formation of Land Grant Universities in each state. Subsequently, State Agricultural Experiment Stations enabled by the Hatch Act of 1887 were established.

These and later acts providing for research and extension in cooperation with the U.S. Department of Agriculture (USDA) established a mechanism which has provided for the discovery and application of extraordinary advances in science and technology to all fields of agriculture, including production of beef.

Longhorns and other cattle native to various areas at the time

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were slow maturing. Steers were grazed until they were four to seven years of age before reaching the degree of fatness desired by the market. Early experiments indicated that the Shorthorn and Hereford breeds imported in 1817 and the Angus imported in 1873 from Britain could be depended upon to sire earlier maturing progeny with a propensity to fatten to a desired market condition by two to four years of age when grazed on native grass.

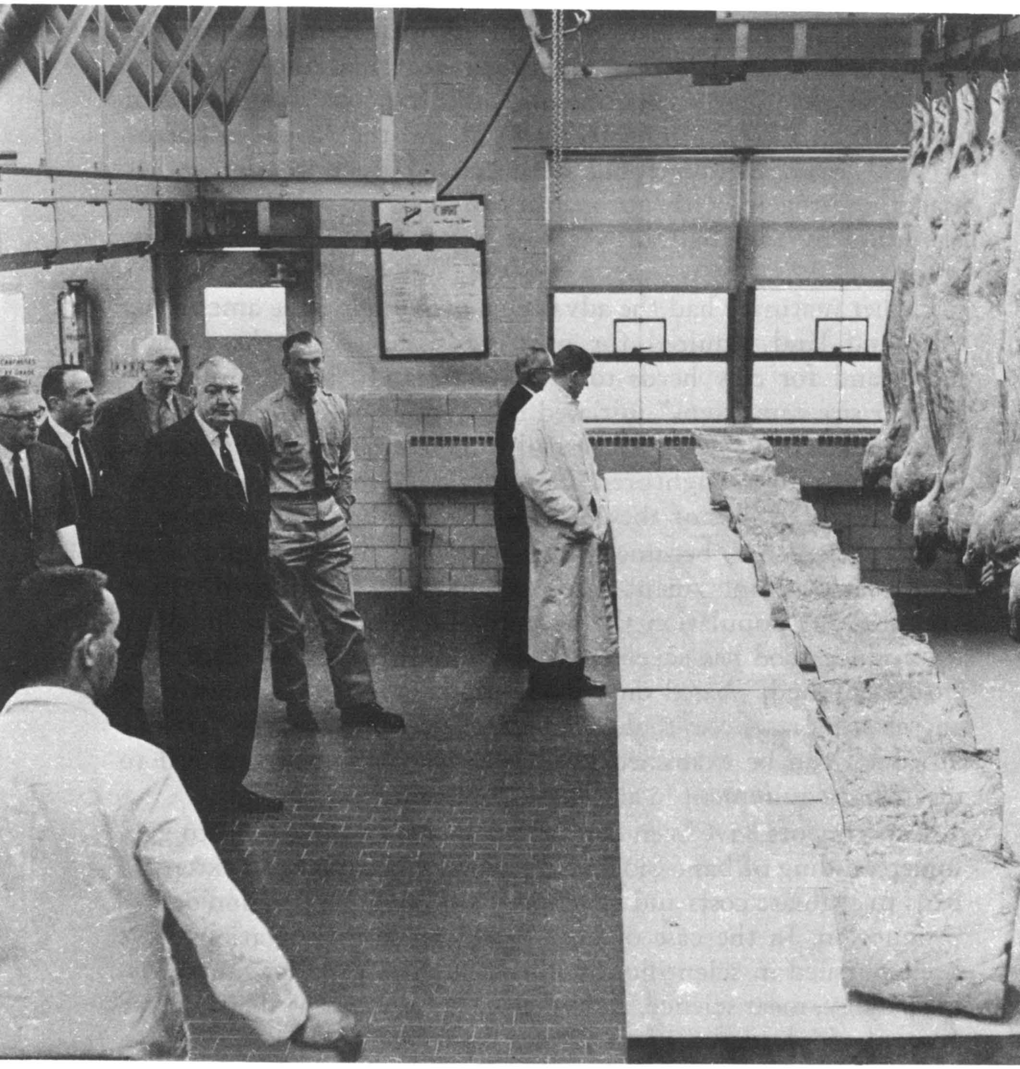
Earlier maturity had the advantage of reducing the amount of time and land required for growing slaughter cattle, freeing more land for cow herds to produce greater amounts of beef. "Better sire campaigns" initiated by State Extension and USDA personnel in 1908 were successful in converting the beef cattle populations to straightbred Herefords, Angus or Shorthorns, using purebred sires of these breeds.

As agriculture became more efficient, more people were available for employment in other industries. And with an increase in our population the need for food and new technology to produce food has accelerated at an increasing rate. The "Scientific Method," based on consideration of previous knowledge and existing resources to develop hypotheses or ideas, the veracity of which can be examined by experiments, has been applied to meet this requirement in all fields of agriculture.

Experiments have been conducted on an intensive basis to gain understanding of basic biological phenomena, and on an extensive basis to evaluate costs and benefits of applying new technology to production. In the case of beef cattle, these investigations have been pursued in scientific disciplines such as genetics, nutrition, physiology, meat science, and veterinary medicine as they evolved from the biological sciences. Other disciplines such as marketing, production economics, and engineering also have played an important role.

For example, principles of population genetics were developed by Sewall Wright in the 1920's from experiments with guinea pigs conducted by USDA. Adaptation and extension of these to farm animals by Jay L. Lush, at Iowa State University in the 1930's and 1940's, provided the basis for much of the genetics research with beef cattle.

Most of the beef cattle breeding research has been conducted since 1946, when Congress passed the Research and Marketing Act which encouraged the organization of research on a regional basis. Regional projects focusing on improving beef cattle



Penn State researchers show cattle producers the results of performance testing of meat animals.

through breeding methods have been conducted cooperatively by State Agricultural Experiment Stations, and USDA Agricultural Research Service stations in the North Central, Western and Southern States.

Early in these projects fertility, growth rate, efficiency of growth, and carcass desirability were recognized as the major economic traits contributing to efficient production of desirable beef.

Cattle varied significantly in these characteristics. Research determined the amount of the variation that was heritable and procedures for measuring these characteristics to maximize effectiveness of selection.

Results indicated that the differences in growth rate between animals within a breed were highly heritable and that selecting breeding stock on the basis of superior growth rate would lead to improved growth rate, feed efficiency, and increased value of retail beef produced per unit of cost in subsequent generations.

As a result, beef cattle improvement programs based on records of performance were initiated under the guidance of the Cooperative Agricultural Extension Service in most states in the 1950's. Subsequently, national organizations—including most breed associations involved with registering purebred cattle—initiated record of performance programs as a service to their breeders and a vehicle for breed improvement.

Sire Evaluation

National sire evaluation programs are beginning to emerge whereby sires can be compared to each other on the basis of their progeny. Those that are most outstanding can be used throughout the breed by artificial insemination to accelerate genetic improvement.

Selection within breeds can make a steady continued change, but this is a relatively slow process which alone will not be sufficient to meet projected demands for increased production of beef. Also, it was found that reproduction could not be improved appreciably by selection within breeds. Experiments on inbreeding (the mating of close relatives) revealed that inbreeding reduced reproduction, survival, and early growth rate.

Crossbreeding experiments have demonstrated that hybrid vigor can unlock depressing effects of inbreeding that have slowly, but inevitably, accumulated over many generations of purebreeding.

For example, an experiment involving Herefords, Angus and Shorthorn crosses and straightbreds has revealed that production per cow can be increased 23 percent due to effects of hybrid vigor on increased survival and growth rate of crossbred calves, and on increased fertility and milk production of crossbred cows. More than half of this advantage is dependent on the use of crossbred cows.

Results such as these have had profound effects on breeding systems employed in the industry. It is conservative to estimate that more than half the cattle marketed today are crossbred as compared to a very low percentage 10 years ago (two generations in cattle breeding) and their numbers are increasing rapidly.

The incorporation of crossbreeding into commercial production has been accompanied by the importation of a number of new breeds into North America from other countries via quarantine facilities of the Canada Department of Agriculture.

Interest in these and other breeds, such as dairy breeds and dual purpose breeds that have had a limited impact on beef production, has accelerated. Thus, the germ plasm base has been extended to include a wide range of biological types represented by breeds varying widely in characteristics such as milk production, growth, mature size, and carcass composition.

The optimum choice of breeds and system of crossbreeding may very well differ, depending upon the quantity and quality of feed supply (for example, feed grains *vs.* forage, or arid and semi-arid ranges *vs.* lush meadows) and demands of the market (trend toward less fat).

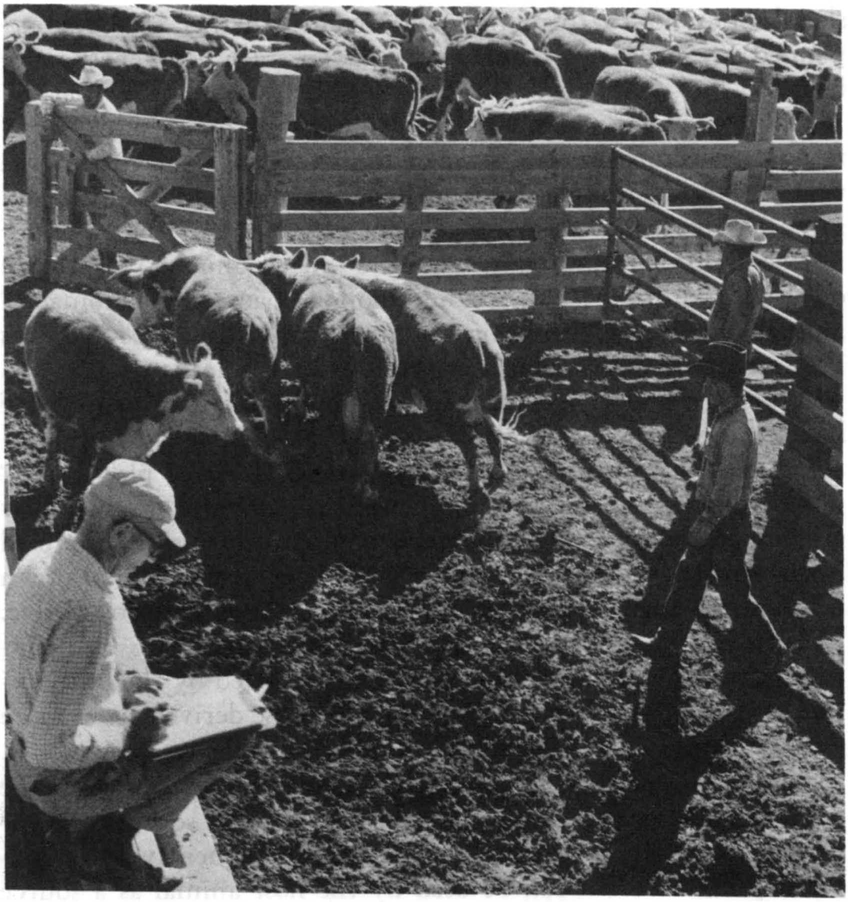
Experiments are in progress to characterize these breeds in different feed environments and production situations for the full range of biological traits influencing economic production of beef.

A coordinated approach involving scientists from a number of disciplines including genetics, nutrition, physiology of growth and reproduction, meats and management systems is required to learn how to best synchronize variable germ plasm, feed and other resources with market requirements.

The "Scientific Method" has been used by nutritionists on an intensive and extensive basis to identify the nutrients (carbohydrates, fats, proteins, vitamins and minerals) required for efficient production of beef. Research has also established analytical procedures whereby various forages, cereal grains and potential feedstuffs such as industrial by-products can be evaluated for their nutrient and chemical content.

Results from hundreds of experiments at Agricultural Experiment Stations have been compiled into nutrition standards for beef cattle. They are used in the industry considering the supply and cost of alternative feedstuffs, to formulate rations that minimize the cost of production.

This research has been accompanied by extraordinary ad-



Performance-selected sires added 150 to 200 pounds per animal to long yearling weights, in this purebred herd of 1,500 cows owned by the San Carlos Apache Tribal Council. An Arizona scientist cooperated in the cattle improvement efforts.

vances from research in plant, soil and agricultural engineering sciences providing for more efficient production and harvesting of vast quantities of corn, sorghum grains, soybeans and other crops.

Similarly, advances in veterinary science relating to animal health, and engineering providing for mechanization in feed processing, have contributed to the formation of a feed manufacturing and cattle feeding industry involving feedlots carrying from 500 to 100,000 head. These technological advances have been translated into greater efficiency by reducing age at

slaughter to 15 to 20 months and freeing further land for expanded cow herds to produce more calves and subsequently more beef.

Knowledge concerning the site and nature of chemical reactions that occur between intake of feedstuffs and their incorporation into milk, muscle, fat and bone continues to evolve from intensive research.

The ability of ruminants (multi-stomach animals) to thrive on grass and other forages, while monogastric (single stomach) animals required cereal grains or other easily digested foods, has been recognized for centuries. Following the leads of German workers, the underlying mechanisms responsible for this mystery have become more clearly understood.

Cellulose, the primary structural carbohydrate of plants, cannot be digested by salivary or pancreatic enzymes produced by all animals, but the vast population of microorganisms contained in the rumen produce an enzyme (cellulase) which breaks down cellulose to form sugars on which the microorganisms thrive. Volatile fatty acids provided by the microorganisms as a byproduct of this fermentation process are utilized by the host animal as an alternative source of energy to those derived from more easily digested carbohydrates.

Another important advantage of ruminants results from the ability of microorganisms to convert urea or other sources of nonprotein nitrogen into amino acids and subsequently into bacterial protein which can be used by the host animal as a source of protein for growth, lactation, or other physiological activities.

Understanding of this biological phenomenon led to experiments on the use of urea in protein supplements—and their use today in growing-fattening rations to reduce costs of beef production. (Urea is a cheap synthetic chemical).

These unique characteristics of ruminants provide for the adaptation of cattle to a wide variety of feed resources.

Even today when essentially all beef in the fresh meat counter comes from cattle finished in feed lots on relatively high grain rations, about 80 percent of the energy used for beef production is derived from forages that cannot be utilized by nonruminants.

These characteristics assure that beef will remain an enjoyable source of protein, even in the future when cattle can no longer compete economically with humans and other animals for cereal grains. They will convert crop residues as well as forages grown on nontillable land, which presently includes more than half the

land area in the United States, into beef and milk for human consumption.

Physiology research has provided insight into the effects of hormones produced by various organs in the body and how they interact to regulate growth, lactation, and reproduction. Intensive studies in these areas contributed to the discovery of growth stimulants such as diethylstilbestrol, minute amounts of which nutritionists found could be fed or implanted to increase gains in growing-finishing steers by 10 percent. Similarly, melengestrol acetate (MGA) stimulates growth of heifers about 10 percent.

Freezing Bull Semen

A series of experiments conducted by scientists at a number of Agricultural Experiment Stations culminated in the ability to freeze bull semen, and to extend the use of outstanding sires to produce large numbers of calves out of cows in many herds by artificial insemination (AI).

This is likely the most significant development from reproduc-

Taste panel evaluates meat products in Pennsylvania.

tive physiology research to date. It has been followed by development of an AI industry which has had a great impact on dairy cattle production. AI is experiencing a growing impact on beef production, especially since it has been the only means of introducing recently imported "exotic" breeds into beef production in the United States.

Criteria for evaluating differences in carcass composition relating to percentage of lean, fat, and bone have been evaluated by meat scientists. These findings have been incorporated into yield grades used in market channels to reflect differences between carcasses in value of edible beef.

Meat science has also included the study of factors such as alternative processing procedures, refrigeration, and freezing on beef quality relating to tenderness, flavor, acceptability and shelf life in the meat counter.

Technology such as this—combined with research and developments by industry—have all contributed to the efficiency with which beef is processed, transported and marketed to provide a steady supply of wholesome, safe, nutritious and palatable food which usually serves as the main course on the table for family and guests.

These are but a few technological advances from research provided to the U.S. beef cattle industry since its inception with Longhorn cattle. Other examples from these and other disciplines could be cited.

The rate with which new technology has been applied has been equally phenomenal. Cattle producers and feeders, like producers of all agricultural products, have shown unprecedented ingenuity and uptake of innovations and new technology. As a result, production costs have been significantly reduced.

Americans spend less of their disposable income for food today than in 1940. During this period beef has become the most popular source of dietary protein. As family income has increased, per capita consumption rose steadily to over 116 pounds in 1972, approximately 60 percent of the red meat consumption.

Continued importance of beef as a palatable source of dietary protein seems assured by the adaptation of beef cattle, as ruminants, to a wide range of feed resources including crop residues, grasses and other forages. The challenge of beef cattle research is to provide further technology to assure that these feed resources are more efficiently utilized in order to meet the ever increasing demand for beef of acceptable quality.

How Chicken on Sunday Became an Anyday Treat

BY ROBERT E. COOK, HARVEY L. BUMGARDNER AND WILLIAM E. SHAKLEE

Broilers . . . in elegant restaurants, short-order cafes, carry-out food establishments, in the home, and on the grill in the backyard . . . are part of today's American culture.

Only three decades ago Americans depended on countless backyard flocks to provide them with chicken for the table. Today, however, broiler production is industrialized in much the same way as the production of cars, shoes or TV sets.

Revolutionary changes in production and marketing have transformed the backyard flocks into the modern efficient U. S. broiler industry. These changes resulted from the teamwork of the Industry, the State Agricultural Experiment Stations, and the U. S. Department of Agriculture (USDA).

Advances have been directly related to research developments. Application of these developments changed the broiler from an expensive special occasion food to an abundant low cost staple that everyone can afford.

The chicken is not a native American bird. It came to this continent with the first European settlers. There were small home chicken flocks at Jamestown, Virginia, in 1607, but those chickens and the methods used for growing them had little in common with the more than three billion broilers now produced each year in the United States.

The story of the growth of broiler production from small backyard flocks to the enormous industry of today is paralleled by a story of scientific breakthroughs made in the agricultural experiment stations.

With all of today's gadgetry, it is easy to forget the way Mother

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Nature does things. In nature, a hen sits on her eggs, warming them for 21 days. That is Mother Nature's way of incubation. But man has been trying to improve on nature for thousands of years. The ancient Egyptian and Chinese civilizations developed crude artificial methods of incubation.

Although the first American incubator was invented about 1844, it was not until the 20th century that the predecessor of today's huge scientific incubation machine came along. In 1918 Dr. S. B. Smith patented his room-sized forced draft incubator. On the heels of Dr. Smith came Ira M. Petersime in 1922 with the first electrically heated and electrically regulated incubator.

Today's broilers start as day-old chicks from the gigantic incubators in hatcheries that produce up to one million or more chicks a week.

But let's look back for a minute at the chickens in the backyards of our forebears in Jamestown. They were pretty scrawny birds. Maybe they were big enough to eat by the time they were six months old.

Today's broiler, thanks to researchers in the Agricultural Experiment Stations and to poultry breeders, weighs four pounds before he reaches nine weeks of age. He is fed better, housed and cared for better, and pampered in many ways. He is also a different bird genetically.

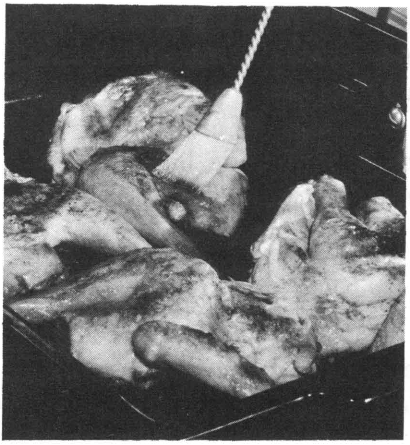
Genetic improvement of the broiler really began about 1940. The State of Georgia was emerging as an important area for broiler production. Alert poultry scientists at the State's land grant institution, The University of Georgia, recognized a need of the broiler growers and set about to satisfy it.

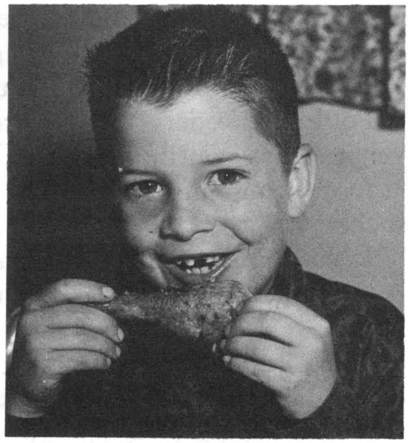
In 1940 the Georgia Poultry Breeder's test began. Identifying genetically superior chickens that would produce bigger, better and more efficient chickens was the purpose of this test.

Speaking to a group of poultry producers in 1944, Howard Pierce, national poultry research director of A & P Food Stores, threw out a challenge to the Poultry Industry. He suggested that the industry seek improved chickens for meat in the same manner that agricultural science had produced broad breasted turkeys.

The remark was editorialized in the poultry press, and the American poultry leaders accepted Mr. Pierce's challenge. Realizing that producers and consumers alike would benefit through development of superior meat-type chickens, A & P offered to sponsor a program promoting the idea.

The campaign began. Representatives of ten national poultry organizations, three leading USDA poultry specialists, and two





Left, basting broiled chicken in an oven. Right, youngster ready to dig in despite a missing tooth.

poultry magazine editors met in 1945 in Chicago, and the National-Chicken-of-Tomorrow Committee was formed.

Committees in 44 states from coast to coast were set up to supervise the local phase of the contest, a contest to breed and grow the best meat type chicken.

State contests were held in 1946, state and regional trials in 1947, and in 1948 at the University of Delaware's Agricultural Experiment Station the national finals were conducted.

Leading up to the finals, poultry breeders were experimenting with various types of breeding and cross-breeding. Their goal was to produce chickens with broader breasts, thicker drumsticks, flatter and broader backs, unblemished skin, no pin feathers, and no general undesirable characteristics.

Barnyard Revolution

The Chicken-of-Tomorrow Contest was a barnyard revolution. It fundamentally changed meat-type chickens. It proved that much improved chickens for table use could be produced economically and profitably, and people in the poultry industry were interested in doing just that.

The contest was designed to reduce the costs of producing chickens, not to get a higher price for them. It was an effort to get the premium on the production end through lower feed costs, shorter growing periods, and more meat. The contest was a definite success.

When the Chicken-of-Tomorrow Contest began, the accepted national feed conversion ratio was four pounds of feed to one pound of chicken. Now it is two pounds of feed to one pound of

chicken. When the contest began, it required 14 to 18 weeks to produce a chicken that weighed four pounds. Today a four-pound chicken is raised in less than nine weeks.

Poultry breeders and research workers at Land-Grant Universities are continuing their efforts to provide better broilers at more economical prices. The consumer continues to enjoy their successes.

It's a dramatic story—the story of the scientific breeding of a better chicken for American tables and for tables all over the world.

Just as dramatic are the discoveries that make the diets of today's chickens more nutritious and more efficient than the diet that most people eat each day.

Chickens of early America roamed at will in backyards and in barn lots and scavenged for their food. The housewife or the farmer threw them a little grain, but for the most part these backyard chickens found their own food. They balanced their diet as their wild jungle fowl ancestors of India did, by catching bugs and insects and by eating grass and grass seed. And they had sunshine.

"Complete" Poultry Feeds

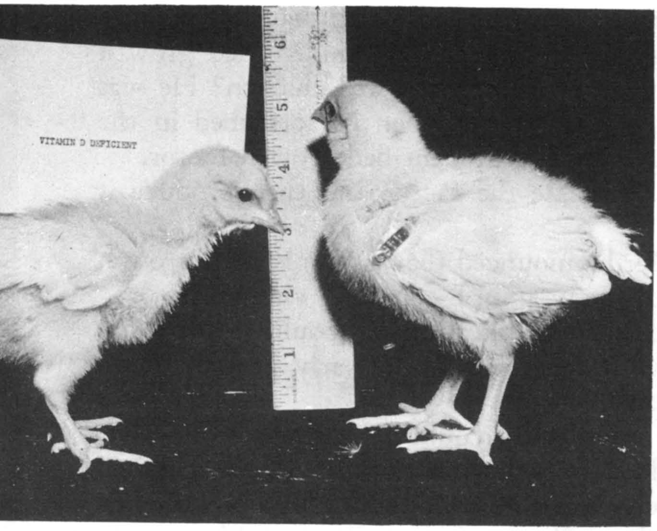
Early attempts to improve the living conditions of the chicken were failures. Chickens were brought into houses and their food was provided for them. But they didn't grow. Hens layed few eggs and young growing chickens developed rickets. Why? They had no sunshine, and it is sunshine which makes it possible for chickens and other animals to manufacture vitamin D in their own bodies.

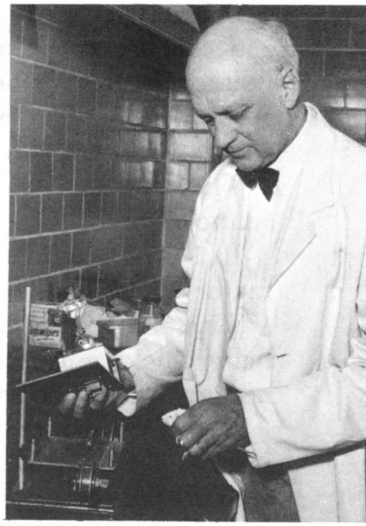
For a long time the American consumer could enjoy frying chickens or broilers only in the summer months from eggs layed in the spring.

The discovery of vitamin D revolutionized the poultry industry. In 1930 cod liver oil as a source of vitamin D was mixed into poultry feeds. Since then it has been possible to raise poultry indoors and in all seasons of the year.

We still don't know the exact number of vitamins. In fact, man's first knowledge of these health-promoting substances dates back only to the beginning of this century.

We do know that the growing chicken, or broiler, needs at least 13 vitamins. We add 12 of these to the feed we manufacture for him. The 13th, biotin, is found in many feed ingredients and is also manufactured by the chicken in his intestinal tract. Bits of





Normal and vitamin D-deficient chicks in early nutrition experiments in Wisconsin. Harry Steenbock, shown with laboratory animal, discovered that the sun's ultraviolet (UV) rays were the source of vitamin D, and that exposed surfaces trapped and stored the vitamin. This led to enrichment of foods and successful growing of chicks under artificial light when UV was added to the spectrum. The giant broiler industry and widespread use of vitamin D-enriched foods stemmed from these discoveries.

information and clues used to unravel the mystery of the vitamin needs of broilers were provided by hundreds of workers.

It is hard to credit any single person with the discovery of any one vitamin and the documentation of its need by broilers. In almost every case clues were provided by many scientists in State Agricultural Experiment Stations.

One of the most exciting cases involves the discovery of the last of the known vitamins. In 1949 vitamin B_{12} was discovered, making it possible for us to develop "complete" poultry feeds.

For years scientists knew that an unidentified growth factor was present in certain animal proteins. Broilers grew better if such things as liver meal, fish meal, meat scrap or milk by-products were included in their feed. Poultry nutritionists in Agricultural Experiment Stations all over the United States joined in the search to identify this substance.

They scored another victory for the American farmer—and the American consumer—with the isolation of the animal protein factor. The victory was won following thousands of man hours of research.

Before the victory came, scientists had found that cow manure and chicken droppings also contained this unidentified growth factor. Remember our backyard or barnyard chicken? He was getting more than bugs and worms when he scratched in the cow lot. He was also getting this unidentified growth factor.

The next step was to isolate the factor and then produce it artificially.

In 1949 Dr. H. R. Bird announced that this unknown growth factor was a member of the vitamin B complex: vitamin B_{12}.

Vitamin B_{12} found great application in poultry nutrition. Baby chicks must have it for survival and early growth. Hens need it to produce hatchable eggs.

The discovery that vitamin B_{12} could be synthesized in laboratories opened the door to unlimited supply. Pharmaceutical laboratories immediately began its production. Vitamin B_{12} improves the value of the millions of tons of vegetable protein meals used in poultry feeds. Less animal protein meals are needed, and the cost of broiler feed and of the broiler itself is reduced.

Vitamins are important, but there are many other important considerations in mixing a broiler feed. Calories, for example.

A chicken has a relatively short and simple digestive tract. This limits the quantity of feed that a broiler can eat. Broilers need a feed with lots of calories per pound so they can grow into big tasty chickens.

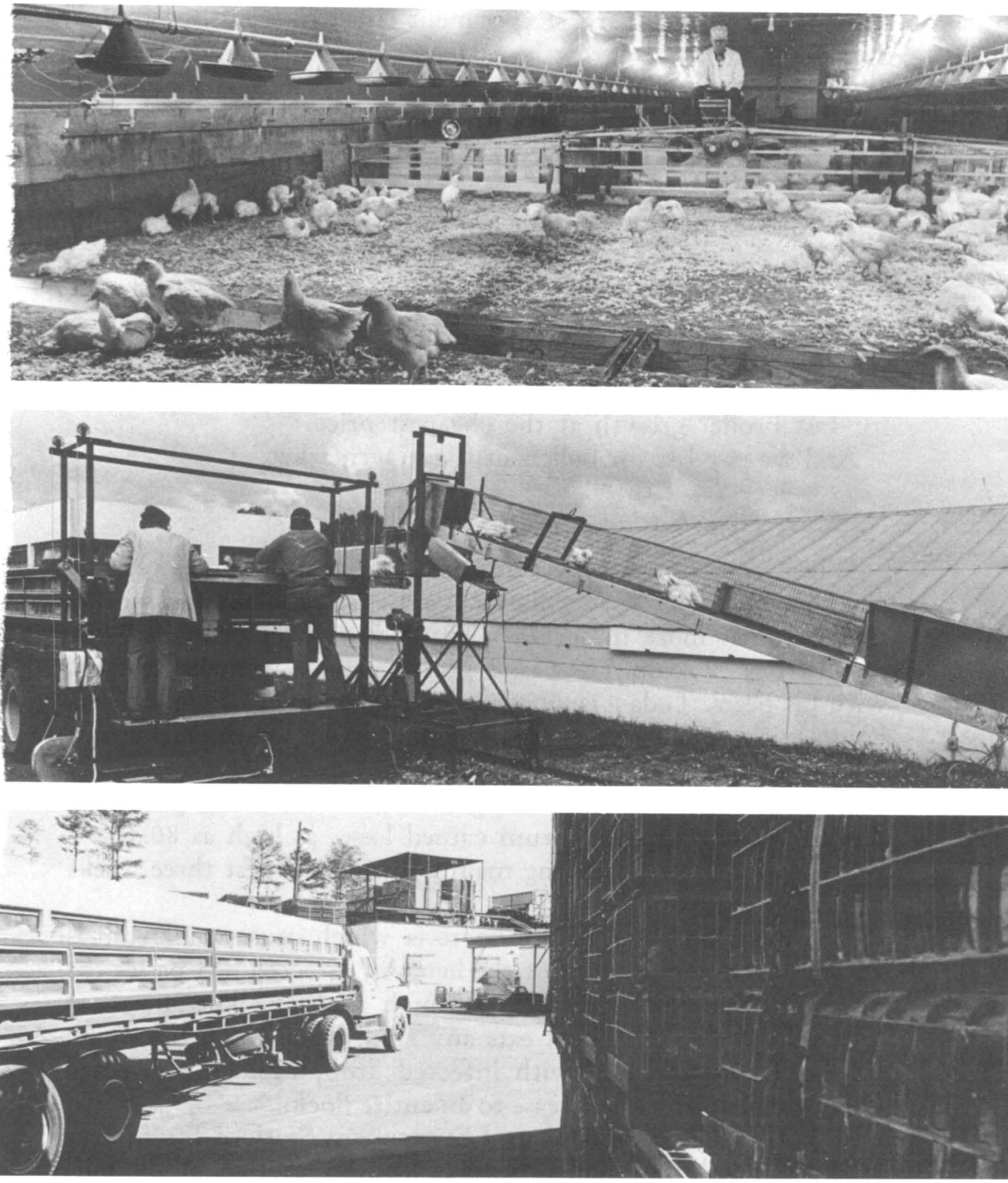
In 1949, scientists at the Connecticut Agricultural Experiment Station produced a feed that met this need. It contained about 70 percent corn and was consequently high in calories.

Feed manufacturers went to work in earnest and came out with adaptations of the Connecticut feed that met two requirements. The feeds were high in calories and they were economical to produce. The manufacturers coined the phrase "high-energy feed" to describe their new product.

Stress in the Broiler World

A constant problem in broiler production is stress. Stress includes such things as extremes in temperature, disease, crowding, and poor management. One or more of these is almost invariably present in broiler production and stress slows growth in the broiler.

In 1950, researchers discovered that depressed growth caused by stress is overcome by adding antibiotics to the broiler's feed. Feed manufacturers now routinely include antibiotics in broiler feeds, and broilers grow faster than ever.



Mechanical harvesting broiler operation, developed by Georgia scientists, which results in less bruising of birds than hand harvesting. Top, electric-powered herder pushes chickens onto conveyor belt in foreground trough. Birds are docile under normal blue light. Center, conveyor belt takes chickens from broiler house to three-tiered transport vehicle designed to fit in with system. Above, new vehicle at left contrasts with traditional transport of broilers in stacked cages.

In 1952, Agricultural Experiment Station scientists found that, for best broiler growth, calories and protein must be balanced. Electronic computers entered the broiler feed picture in 1970. Linear programming with a computer is now a widely used mathematical technique in the poultry feed manufacturing industry.

Two kinds of information are put into the computer. One describes the kind of feed needed. The other includes all the possible ingredients that might be used in producing the feed and the cost of each. Supplied with this information, the computer calculates the cheapest combination of ingredients to satisfy the standards for a high quality feed. In other words, the best feed for fast broiler growth at the cheapest price.

And we pay less for boilers at the supermarket.

National Health Plan—for Broilers

When you increase the number of animals, people, pigs or chickens in a given space, disease is a bigger problem and sanitation becomes more important. The backyard chicken had lots of territory to roam. He wasn't grown in such intimate contact with his peers. Today 10,000 broiler chicks can be raised in one house with few losses because of improved management and disease control methods.

One of the first diseases brought under control was pullorum disease. At one time pullorum caused losses as high as 80 to 90 percent of a flock, occurring mainly during the first three weeks of life.

The main reservoir of the bacteria which causes pullorum is the egg-producing organs of the hen. An infected hen passes the disease to her chicks directly through the egg. The disease is transmitted also if a chick eats any feed, water, or litter which has been contaminated with infected droppings. One infected chick can transmit the disease to an entire flock.

Scientists at the Agricultural Experiment Stations found that a simple blood test could be used to identify carriers of the pullorum bacteria. By eliminating these carriers from the breeding flock, chicks can be hatched free of the disease.

In 1935 USDA established the National Poultry Improvement Plan in cooperation with state poultry improvement associations. Part of this plan was a program for controlling pullorum disease. Today this once deadly disease has virtually been eliminated from U. S. poultry flocks.

Streamlining the Hog, an Abused Individual

BY RUTH STEYN

Stupid, greedy, bad-tempered, dirty, and fat. The storybook image of hogs is uncomplimentary in the extreme. But let that little pig, or rather 220-pound hog, go to market, and the tune changes. Then we enjoy juicy ham, tasty spareribs, sizzling pork chops, and the hotdog.

Many of the epithets directed toward hogs are unjust. By nature they are among the cleanest of animals. If given a choice, domestic hogs—like their wild ancestors—will choose a clean place to sleep and wallow. And in properly designed buildings, hogs learn to deposit their wastes in gutters, which are flushed with water, so that the main part of the pen stays clean.

The supposed gluttony of hogs probably reflects their unselective diet more than its quantity. The omnivorous hog will eat most everything from acorns to zucchini, including weeds, potatoes, sugar beets, and grasshoppers. Of course, the diet of modern American hogs is more restricted, consisting largely of corn plus various protein, vitamin, and mineral supplements. But regardless of its exact diet, the hog is a rapid, prolific, and relatively efficient meat-making machine.

Undoubtedly the ponderous, jowly, short-legged hog typical of the early 20th century deserved to be called fat. Some 35 pounds of lard were cut from each 180-pound carcass in those days when hogs were raised as a source of both lean meat and animal fat.

Before the development of petroleum and its products, lard was an important lubricant and lighting fuel. Prior to development of synthetic detergents, a great deal of lard was used in soap making. And until the advent of cheap vegetable oils, lard was a favorite shortening in America's kitchens.

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As substitutes for lard became dominant during the 1930's and 1940's, consumer tastes also changed. With less physical toil and more sedentary occupations, people needed fewer calories and wanted leaner, meatier pork. The lard-oriented swine industry, adapted to the needs of early Americans, was in deep trouble. Lard prices declined. Pork consumption per capita decreased. What was needed was a pig that would convert our readily available corn and soybean meal into high-quality lean meat, or protein, instead of into fat.

Even before 1900, scientists at several State Experiment Stations had discovered that the protein and fat content of pigs differed among breeds, types, and grades. However, these early experiments were limited in scope and did not lead to significant decreases in the fat content of hogs.

By the 1930's it was evident that a systematic and extensive breeding program was needed to develop meatier hogs, improve the reproductive performance of sows, and increase the growth rate and feed efficiency of pigs destined for market. A coordinated

effort to achieve these goals was launched in 1936 with establishment of the Regional Swine Breeding Laboratory at Ames, Iowa. The Swine Laboratory is supported by the U.S. Department of Agriculture and State Experiment Stations in the Midwest, center of U.S. hog production.

About this time, corn breeders discovered the potential of heterosis, or hybrid vigor—the increased growth and yield of offspring produced by mating (or by the crossing) of two pure lines of corn. Would hybrid vigor show up in pigs when a sow of one breed was crossbred to a boar of a second breed?

Controlled experiments at State Agricultural Experiment Stations soon proved that crossbreeding led to larger and heavier litters, lower death rates of young pigs, and faster growth rates. For farmers, crossbreeding meant about 20 percent more pork produced per litter. For consumers, it meant lower pork prices due to the increased efficiency of production.

More "Mothering Ability"

Early crossbreeding was strictly for market hog production. That is, the pigs fed and slaughtered for market were crossbreds, but both parents were purebreds. Additional studies showed that crossbred sows, whose inheritance stemmed from two different breeds, had greater "mothering ability" than purebred sows.

A crossbred sow, when mated to a third breed of boar in a so-called three-way cross, produces more pigs and stronger pigs than a purebred sow. The crossbred mother also gives more milk, which helps the young pigs to survive their rather hazardous early days.

Introduction of crossbred sows further increased the efficiency of pork production. At five months of age, litters from three-way crosses were 40 percent heavier than purebred litters. Because the cost of feeding and caring for a sow is about the same regardless of the number, size, or survival of her offspring, superior maternal performance reduces the per-unit cost of producing pork, a saving that can be passed on to consumers.

Baby pigs face numerous hardships that often kill 20 to 30 percent of a litter during the first week or two after birth. Forty years ago, the sow herself was a big threat to her offspring. A three-pound piglet had little chance of surviving if its 500-pound mother accidentally rolled over onto it.

The modern farrowing crate, developed and tested at several State Experiment Stations during the 1950s, makes life a lot

safer for young pigs. Although several types of farrowing crate are used today, the basic principle of all is similar. A restraining frame around the sow confines her during and after birth of the young. This prevents her from lying on the baby pigs, but allows them to reach the sow for nursing.

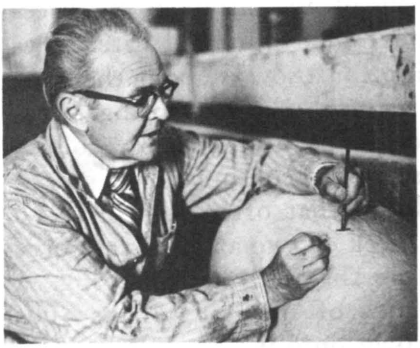
Before the farrowing crate, the swine producer had to be on hand at farrowing time, or risk losing valuable baby pigs. The farrowing crate saved producers a lot of time, labor, expense, and sleepless nights spent rounding up and protecting vulnerable baby pigs.

Although these changes all increased the efficiency of hog production, they did little to satisfy the need for less fatty, leaner hogs. In the late 1940's, Lanoy N. Hazel at the Iowa Experiment Station realized that a method of measuring the amount of fat on live animals was essential for selecting and breeding meatier hogs. The traditional method of determining the fat content involved killing an animal and examining its carcass. Unfortunately, when a particularly lean animal was found in this manner, the hog obviously no longer could be bred.

Hazel had several ideas for measuring fat on live pigs. But all were fairly complicated and impractical for screening large numbers of hogs to find the few superior animals with less fat. Finally, following up a colleague's suggestion, Hazel tried an absurdly simple technique that worked.

A 10-Cent Ruler

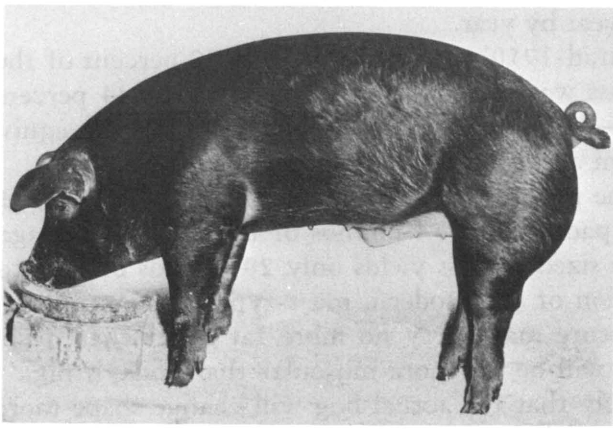
He made a small incision in the skin on the hog's back, pushed a 10-cent ruler through the fat until it reached solid muscle un-

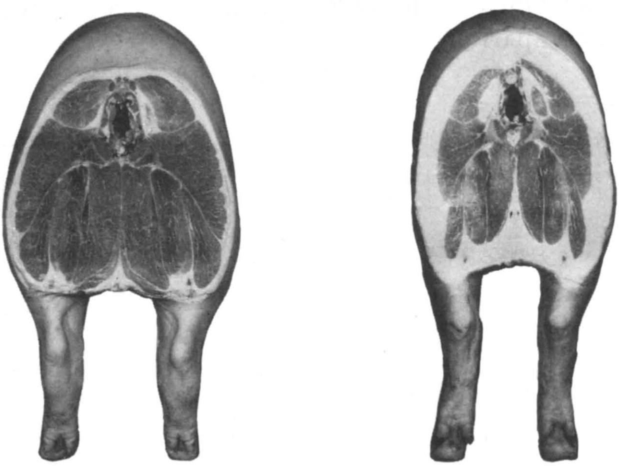


Left, Lanoy N. Hazel demonstrates backfat probe. Right, modern ultrasonic probe records both fat layers and loin eye area on live animals.

derneath, and read off the thickness of the fat cover from the ruler. Since most hog fat is uniformly distributed outside the lean meat, this method provided a good indication of how much fat a hog carried.

In essence nothing more than a narrow ruler, the backfat probe opened the door to scientific, selective breeding of meaty hogs. The original backfat probe underwent several modifications. Today ultrasonic probes are used to measure the fat layer and lean loin portion of live animals, and breeders can accurately identify and select for breeding those hogs with less fat and more lean meat.





Top, a meat-type Duroc hog. Above, carcass of meat-type hog at left contrasted with that of old-style hog.

With development of the backfat probe, commercial hog producers became more interested in evaluating the performance of their hogs. Live boar testing stations were set up in the major pork-producing States. At these, young boars from different herds are raised under uniform conditions. Their average daily gain in weight, backfat thickness, and feed efficiency (pounds gained per pound of feed consumed) are measured. Boars that perform well are then used in breeding herds where their superior qualities can be passed on to many offspring.

The backfat probe and swine testing programs set the stage for evolution of sleek, meaty hogs. As leaner hogs were identified, selected, and bred together, the hog's shape gradually but steadily changed year by year.

In the mid-1950's, for example, only 32 percent of the average hog carcass was ham and loin. Today, about 44 percent is ham and loin—an increase of lean-pork yield by the equivalent of half a ham and a third of a loin per hog.

And the pig was shedding its now largely useless layer of fat. In 1955, packers cut 34 pounds of lard off the average carcass. The same sized carcass yields only 20 pounds of lard today.

Evolution of the modern, meat-type hog continues. The hog of the future may carry no more fat cover than a chicken or steer and will be far more muscular than today's pig.

It's likely that the actual hog will change shape more rapidly than its popular image. We still may liken the rotund pigs of yesterday to a fat person. But the trim, lean hog of tomorrow, with muscular hams, small jowls, and little fat cover, won't deserve such a comparison.

Move Over, Milky Way—Our Cows Are Stars Too

By R. P. Niedermeier, G. Bohstedt, and C. A. Baumann

Today's dairy cow is a fantastic producer. Like all mammals, a cow gives milk because she has offspring and must feed it. Since milk is such a nutritious food, she has been developed as a milk producer and today the average cow not only feeds her calf but also provides milk and dairy products for 19 people. Our Nation's 11¼ million milk cows annually produce over 115 billion pounds of milk, thus providing 253 quarts for every person in the United States.

In 1975, Mowry Prince Corinne, a registered 9½-year-old Holstein cow owned by Mowry Farms, Roaring Springs, Pa., completed the highest milk record ever produced in a single lactation by a cow of any breed. In 365 days she produced 50,759 pounds of milk. On her highest test day she produced 180.4 pounds of milk! In a single lactation she produced 23,609 quarts —a year's milk for 64 U.S. families. This new record dramatically demonstrates how the dairy cow has been developed as a producer of human food.

The oldest written records of man show that dairying was developed as far back as 6,000 B.C. Through history the cow has been used as a beast of burden, an object of worship, and a source of meat and milk.

Dairy cattle were not native to America; the first importation came to the United States in 1624. From colonial times to the 1850's, dairying was a family cow business. All of the U.S. dairy breed associations were formed between 1865 and 1885, thus establishing herd books for the registration of cattle.

The dairy industry has grown to provide nearly 15 percent

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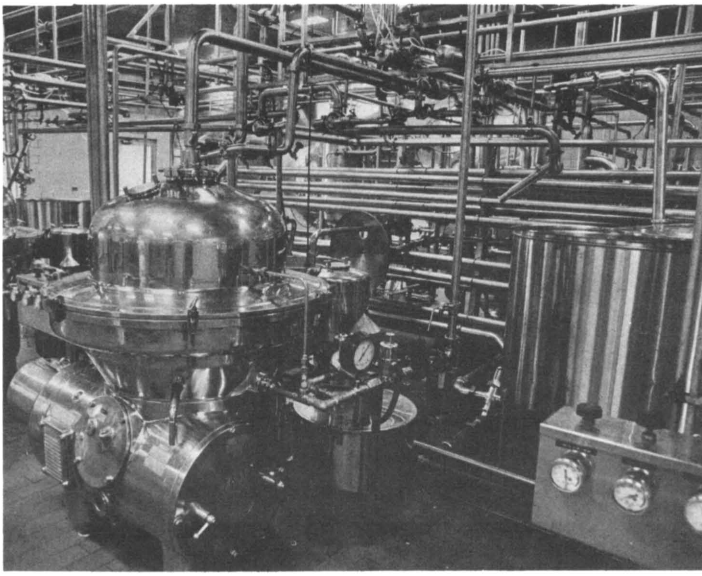
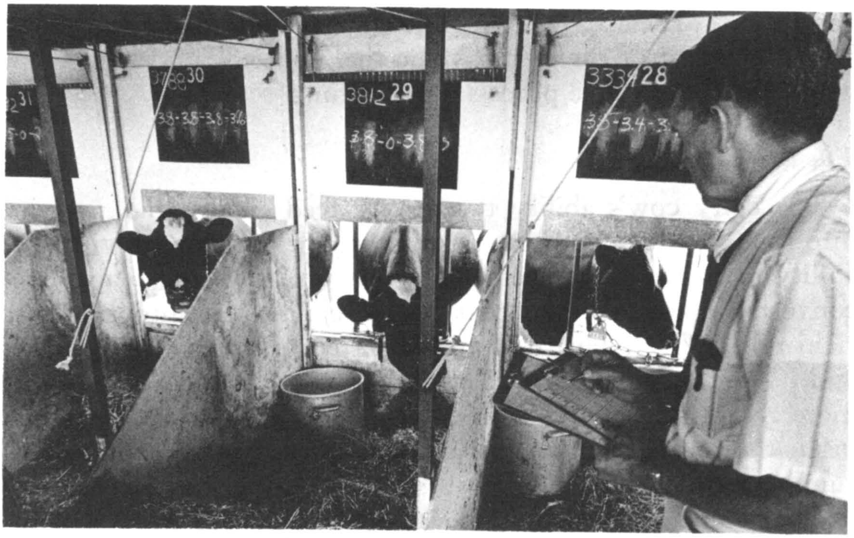


Left, an oldtime cream separator, usually turned by a husky farm boy with muscle-power to spare. Right, modern cream separators are in foreground at this dairy processing plant.

of the total farm income in the United States, and in leading dairy States accounts for 50 to 60 percent of farm cash receipts. Add the cost of processing, storage, distribution and retailing and this agri-business annually represents a $14 billion industry—a big change since the first cheese factory was established in Oneida, N. Y., in 1851.

Today's dairy industry is more than ever before concentrated in the Great Lakes area. Over half of the nation's milk supply is now being produced in the eight States touching the Great Lakes, with other major areas being the northeastern United States and California. Wisconsin is the leading milk producing State followed by California, New York, and Minnesota.

Technology for the production and processing of milk is the result of many factors. The development of bacteriology beginning with experiments by the French scientist Louis Pasteur led to pasteurization, a process used to destroy harmful bacteria in milk. The centrifugal separator invented by DeLaval provided a fast, convenient means of mechanically separating milk and cream. The Babcock test, perfected by Dr. Babcock in 1890, made possible an accurate chemical test for quality that has been used for milk payment and production records.



Holstein cows at Utah State University Dairy Farm.

Control of possible milk-borne diseases such as tuberculosis was essential. A test and slaughter program begun in 1920 has eliminated this disease from U.S. dairy cattle—the beginning of many health control programs that have assured us a safe, healthful milk supply.

Agricultural research has been and continues to be the key to new technology and increased productivity. This began with the establishment of Colleges of Agriculture by the Land Grant Act of 1862, and the subsequent funding for research in agriculture by the Hatch Act of 1887. In 1914, the agricultural extension service established by the Smith-Lever Act added the dimension of taking information from research farms and laboratories to dairymen and processors.

Extension has likewise provided a means of bringing problems from farms and milk plants to the researchers. Agricultural research in the State and Federal experiment stations is essential if we are to continue to increase our output of animal products from the limited resources available to feed the growing human population.

Adding to a well established heritage of dairying brought by immigrants from Europe when this country was settled have been inventions; development of sciences such as bacteriology, chemistry, genetics and nutrition; the development of agricultural education, research and extension; industrial technology, transportation, and the development of marketing and promotional or-

ganizations. These have been important to our dairy industry. However, most of the credit is due the modern dairy farmer on whose farm the whole process must begin.

The Darkest Place

The dairy cow's ability to convert feed energy and protein into food is outstanding. As a ruminant she is endowed with the ability to thrive on forages such as pasture, hay, and silage. She converts fibrous material that people cannot eat into protein-rich milk. W. D. Hoard, founder of *Hoard's Dairyman,* once said, "The inside of a cow is the darkest place in the world." The more recent science of "ruminology" has helped turn on lights inside the rumen or first compartment of the four-compartment ruminant stomach.

The rumen or fermentation vat which holds up to 50 gallons in a large cow is the home of billions of bacteria and protozoa that digest cellulose, produce many vitamins, and manufacture essential amino acids or excellent protein for the cow either from non-protein nitrogen present in forages or that fed as urea (urea is a cheap synthetic chemical). The ruminant also has the unique ability to digest many waste products of the food and feed industry. By-products from the manufacture of sugar, starch, flour, beer and alcohol are efficiently converted to nutritious foods.

Population pressures have led to suggestions that we shall soon become dependent upon plants for our food supply. It is true that more people can be fed per acre if cereal grains and protein oilseeds are used directly for human food rather than converted by animals into products such as milk and meat. The following quote from one of the opening paragraphs in an article published in the *Agricultural Science Review,* Volume 5, Number 2, "Ruminant Livestock—Their Role in the World Protein Deficit," by L. A. Moore, P. A. Putnam, and N. D. Bayley aptly speaks to this issue.

"Although the emphasis on cereal and oilseed proteins has some basis, relegating animal agriculture to a passive contribution to world food deficits indicates a failure to appreciate the full impact of feed inputs into livestock production.

"We contend that generally accepted concepts regarding the efficiency of livestock production in terms of use of available resources are erroneous. We contend that because livestock use forages and other feeds inedible to humans, the use of limited amounts of cereals as livestock feeds can enhance the efficiency

of producing proteins for humans *in terms of total food resource utilization.*

"Furthermore, there are promising research leads, which, if exploited, can markedly increase the efficiency with which animal proteins can be produced. We also contend that considering the world food deficits solely in terms of amounts of protein or calories may result in answers which will make only the less desired diets available to the 'have nots' and may aggravate the serious sociological problems of the world rather than reduce them."

About 70 percent of the protein of the average U.S. dairy cow is obtained from forages. Recent trends toward heavier grain feeding to high-producing dairy cows can be reversed.

Heavier grain feeding is the result of new technologies which have made grains increasingly abundant and relatively cheap. But with feed grains and soybeans in world-wide demand, we are now experiencing a transition to higher priced corn and soybeans and the importance of forages in dairy cattle feeding will almost certainly increase.

Research has shown that dairy cows can synthesize essential amino acids in the rumen from urea. A. I. Virtanen, Nobel Prize winning scientist in Finland, demonstrated in 1966 that cows on protein-free feed could produce reasonable quantities of milk. Today large amounts of urea are used in ruminant feeds, and research continues to determine methods to increase the levels of urea or other forms of non-protein nitrogen that can be used by high-producing cows.

Research is also being done on the treatment of woody, poor quality forages—such as straw and corn stover (stalks and leaves after the ears are harvested)—to make the cellulose more available for milk production. Through cooperative efforts of scientists working in forestry research laboratories, wood has been treated to enhance its use by ruminants. Wood "molasses" and poor quality forage have also been used as a feed energy source.

Our Need for Milk

A strong argument for a flourishing dairy industry, even in the face of greatly increased population pressure, is the high nutritive value of milk to man. High-quality protein, a generous supply of nearly all of the vitamins, and a rich source of most of the essential minerals make milk the ideal supplementary food.

It is possible to devise a vegetarian diet adequate in protein,

but it is very much easier to do so with milk in the diet. Without milk it is possible, but relatively difficult, to concoct a human diet adequate in calcium. With a reasonable amount of milk in the diet, calcium needs are usually met. Almost automatically milk contains satisfactory amounts of the fat-soluble vitamins, including vitamin D if the milk is fortified, and of the water-soluble vitamins.

Since neither most homemakers nor hardly any of us who eat in restaurants are professional dietitians, private attempts at devising diets low in calories, for example, can lead to inadequate intakes of dietary essentials. But with milk and meat in the diet, our nutritional needs are much more likely to be met.

Are We Producing Enough?

Nationwide, 85 percent of all dairy farmers have gone out of business since 1950. Frequently two or more smaller farms were merged so that the acreage devoted to dairy farming and number of cows was not correspondingly reduced. During this period, milk cow numbers declined 47 percent.

In these same years, milk yields per cow doubled. The average U.S. cow produced 5,314 pounds of milk in 1950 versus 10,291 pounds in 1974. This made it possible to maintain total milk production despite the drastic decline in farm and cow numbers.

Milk yields per cow have increased as a result of improved feeding, improved genetic ability, and better environmental conditions. Space permits citing only a few research findings, with most emphasis on nutrition, that provided the technology for modern milk production. A similar story could be told for research contributions that led to artificial insemination of dairy cattle, sire and cow selection programs, and improved management procedures.

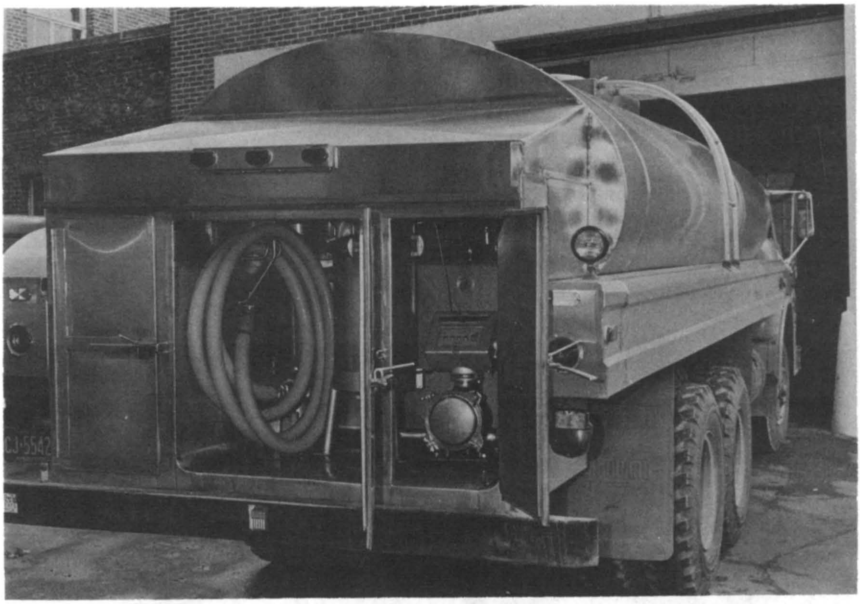
However, a rapidly increasing human population since 1950 coupled with decreasing cow numbers means that today in the United States there is about one cow for 19 people as compared to one cow for 7 people in 1950. Even with the doubling of production per cow, the population increase has reduced the available milk supply from 775 pounds per person in 1950 to only 545 pounds today. A critical point has been reached in the supply of milk in the United States to assure adequate levels of nutrition since milk and milk products contribute so importantly to the Nation's food supply.

Guernsey heifers from an outstanding registered herd in Missouri.

At the beginning of the 1800's, little was known about the chemistry or physiology of plants and animals. A farmer would feed his animals hay and grain, or their equivalents, without being aware of the chemical elements or compounds in them that nourished the animals.

With the march of science and technology and the development of an appreciation of basic aspects of nutrition, feeding standards were advanced. These later standards were based on the chemical content of feeds, primarily the protein, carbohydrates and fat in feeds, but the total instead of the digestible basis was still used. It became apparent that there was a need for more information than the chemical content of feeds.

In 1864 in Germany, Dr. Emil von Wolff presented the first table of feeding standards based on digestible nutrients rather than total nutrients. For every one unit of digestible protein there were to be from 6 to 9 or 10 units of digestible carbohydrates



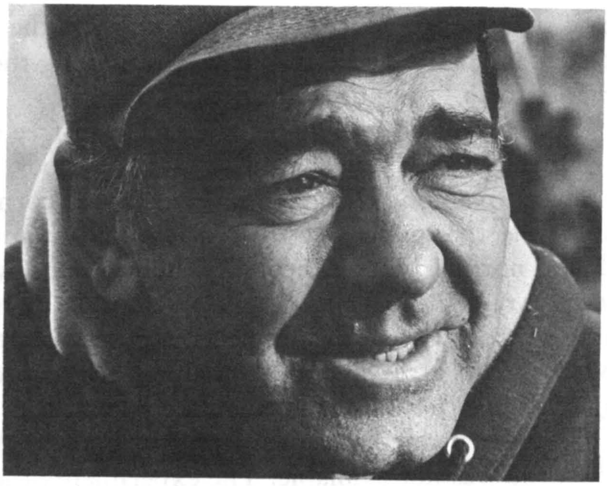
Truck-mounted metering system for farm bulk milk was developed at Penn State, and is said to be first of its kind to commercially measure milk. Such meters are expected eventually to replace present use of calibrated gage rods immersed in milk.

and fat equivalent. The ratio of digestible protein to digestible energy depends on the particular animal and purpose for which it was fed.

The Wolff standards were first brought to this side of the Atlantic in 1874 by W. A. Atwater. In 1880, H. P. Armsby of Pennsylvania State College published a manual on cattle feeding, based on Wolff's work. Subsequently, Armsby refined these feeding standards with the concept of net energy, essentially reflecting the nutritionally depressing effect of fiber or cellulose in feeds. The productive value of a feed or ration varied inversely with the amount of fiber in it.

Despite the logic of balancing rations by digestible protein in relation to kilocalories or megacalories of net energy, this system was not widely used. By far the most prevalent system during the past century has been by the Wolff-Lehmann standard or its modification by F. B. Morrison. This system is based on digestible protein in proportion to digestible non-protein organic nutrients, the so-called nutritive ratio. This may be because of readily understood weighable amounts of nutrients instead of the seemingly abstract concept of calories that do not register on a scale.

During the early part of the past 100 years, there was a fairly

Left, Colorado youngster enjoys a cone. Right, a South Carolina dairyman.

general appreciation of the need for certain minerals by farm animals, such as salt (even the ancients found it indispensable), calcium and phosphorus to avoid rickets, iodine to prevent exophthalmic goiter, and iron and copper for suckling pigs to avoid anemia. The need for other minerals was still largely unknown.

Continuing research revealed the importance of supplementing farm rations with one or the other additional major minerals, and particularly with a still larger number of the minor or trace minerals. Mineral supplement needs varied with soil and climatic or management conditions.

But feeding standards at the time did not specify either kinds or amounts of minerals to use, nor so-called accessory factors, later called vitamins. It was years before some of these micronutrients became farm or household words, as being essential for man and beast.

In 1906, F. G. Hopkins stated: "No animal can live upon a mixture of pure protein, fat, and carbohydrate."

At the University of Wisconsin, Stephen Moulton Babcock had even before the turn of the century doubted the nutritional adequacy of feeding standards then in vogue. There were principles he felt that were not covered by their specifications.

In 1906, as an approach to the problem, he was instrumental in setting up an experiment with four groups of young dairy heifers, growing into milking cows. Each of three groups was fed a ration from a single plant source, the corn, oats or wheat plant. The fourth lot was fed a mixture of all three cereals. In each

case, the forage part was fed along with the grain or concentrate part of the plant, in this way satisfying the current requirements for a "balanced ration".

Salt and, of course, water were allowed free choice.

During two gestation and lactation periods, striking contrasts showed up among the groups. Cows on the corn ration were sleek and fine, the quality of their calves and quantity of milk produced normal or as expected. Those on the wheat ration were in both respects inferior, even disastrous. Performances on the oat and mixed rations were intermediate between those on corn and wheat. The gross chemical analyses for protein, carbohydrate and fat of all rations had been closely identical.

Why then the differences in performance? A ready answer at the time was not available. The experiments themselves had been carried out by Hart and Humphrey, with the cooperation of McCollum and Steenbock. Each of these men was destined to have a distiguished career in nutritional science and to spend a very long and very productive life studying problems that were foreshadowed by the single grain experiment.

The list of their subsequent accomplishments (by no means complete) includes:

- The use of small animals, particularly rats, as a model for determining the nutritional requirements of animals in general—including man
- The recognition of fat-soluble and water-soluble vitamins
- The separation of vitamins A and D
- The identification of carotene as the source of vitamin A activity of plants
- The discovery that vitamin D can be produced by irradiating foodstuffs
- The discovery that copper is a dietary essential

To these must be added fundamental studies on most of the known vitamins and essential minerals, and on fats and proteins, as well as the systematic application of the newer findings (as they became available) to the better production of farm animals. Nearly all of this subsequent work was done within the framework of a College of Agriculture and the Agricultural Experiment Station system.

Of course, many of the newer nutrients proved to be as important to man as to the experimental or farm animals, and the value of basic nutritional research thus was established beyond all question.

A Fish Story Pans Out, and World is Better Fed

By E. W. Shell

This story had its beginning back in 1927 when a group of faculty members at Auburn University organized a fishing club, using a lake that provided the town water supply. Fishing wasn't good so they decided to build their own lake that they could stock and manage. Yet with use of the best information available, the result was one of the poorest fishing holes they had ever fished.

What is unusual is that in this group were several Alabama Agricultural Experiment Station scientists who believed that research could provide the information needed to control the pond environment through management.

As the chapters unfold the story emerges from that of almost complete failure to one of the great success stories in the development of fisheries as a means of recreation, relaxation, protein food for farm and urban people in the depression years, and in our modern day the feeding of millions in the underdeveloped countries of the world.

An entomologist, a plant physiologist, and a soil chemist started it all when they developed a research project for fishery research and presented it to their director. The justification described a vision of farmscapes where each farm could have a fish pond—a place where the family could enjoy "healthful exercise in the open air" and "provide a welcome addition to the family menu" that all too often was sadly lacking in fresh meat in the early 1930's.

The project leaders were an unlikely group to begin aquaculture research, and the one who was to emerge as the leader was

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the entomologist who had been employed to work with pecan insects. His name was H. S. Swingle, a name that became known around the world as the leader of scientific aquaculture. The plant physiologist was E. V. Smith, who later became Dean of Auburn's School of Agriculture and Director of the State Agricultural Experiment Station. The soil chemist, G. D. Scarseth, later became Director of Research for the American Farm Bureau Federation.

Thus the story began but other names were soon added. Names like Lawrence and Prather became part of an ever expanding team dedicated to carry out the vision not only in Alabama but across the nation and around the world.

Their vision has become reality. When Swingle and Smith began their work in 1934 there were an estimated 20,000 man-made ponds in the United States. In 1969 there were an estimated 2.2 million. The Bureau of Sport Fisheries in 1970 estimated that 7.7 million fishermen spent 80 million days fishing in farm ponds—26 percent of all fishermen fishing. The majority of the ponds were managed using techniques developed by Swingle and his fellow workers at Auburn in the late thirties.

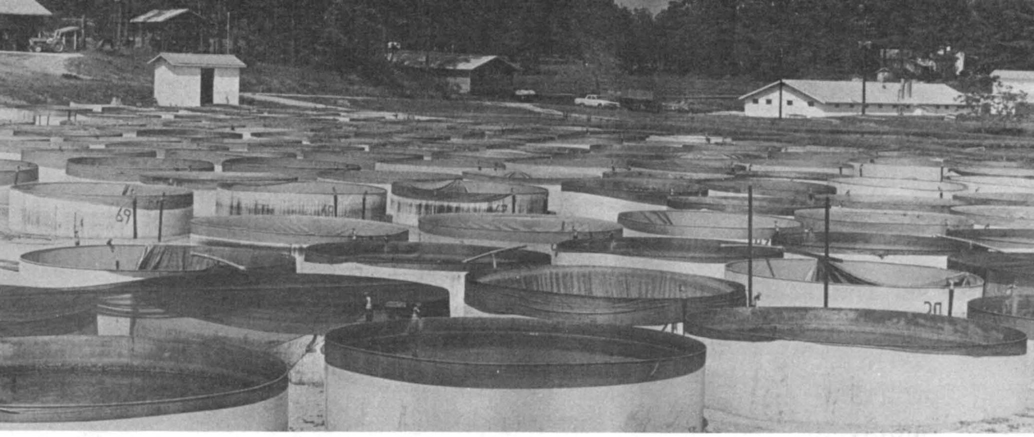
There were practically no fish farms in the 1930's. In 1971 there were 43,000 acres alone of ponds containing catfish. More than 38 million pounds of catfish with an on-the-farm value of over $14 million were harvested. A large percentage of those fish were produced using the techniques developed by this team at Auburn.

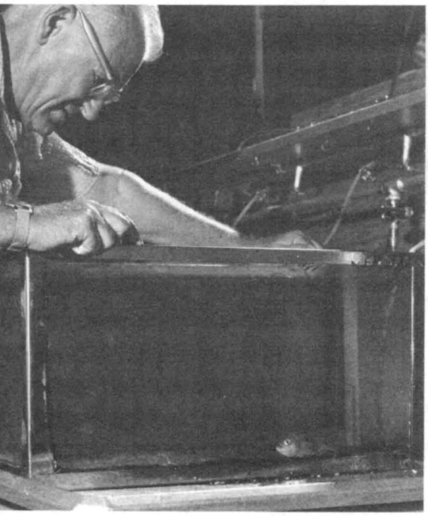
The Auburn scientists built their first pond in the early 1930's. In 1934, construction of 21 experimental ponds was completed and research was underway. Each year since, the pond research facility has been enlarged until it is now the largest warm-water aquaculture experiment station in the world.

The aquacultural pioneers approached the problems of learning to manage small ponds in much the same way that an agricultural scientist might study problems related to corn or cotton production—except that they ran experiments in small earthen ponds rather than field plots.

Fish Give the Answers

Fishery scientists of that day were largely naturalists who learned nature's secrets by observing fish in natural ponds and streams. Swingle and the group of scientists working with him





Top, plastic ponds at Auburn, used for research work today. Left, H. S. Swingle checking on one of his last lab projects. Above, mule teams haul in soil to form dam for one of Auburn's early sport fishing ponds.

learned nature's secrets by asking the fish direct questions by comparing one treatment with another.

Earlier pond and lake management work had demonstrated in both Europe and the United States that fish production in ponds could be increased by adding organic and/or inorganic fertilizers to the water.

Largemouth bass, crappie, bullheads, and bluegills were being produced in state and Federal fish hatcheries and were being stocked in ponds and streams throughout this county. But no one had learned the right number of fish to stock, or the best time to stock them. And no one had found how to use fertilizer correctly to increase production in fishing ponds. It remained for the Auburn group to "put it all together."

In the first experiments the group evaluated a number of species of fish from local streams for their adaptability to life in

ponds, and studied the effects of various types of inorganic and organic fertilizers on the growth of natural fish food in ponds.

Results pointed to the bluegill sunfish as an obvious choice for one of the species that should be included in ponds, and revealed that the amount of natural food rather than the number of fish was the primary factor limiting the production of fish in ponds. From other experiments the group learned that bluegill produce too many young fish in a pond and without some form of population control, the number of bluegill quickly outstrip their food supply.

Prior to Swingle's work, most instructions on pond management warned against stocking largemouth black bass or crappie in ponds with other fish because these two kinds were "fish eaters" and were expected to eat all the other fish in the pond. After much discussion, the Auburn scientists decided a "fish eater" was exactly what was needed, so they began work to determine the proper number of "fish eaters" to include in the pond. These experiments quickly led them to discard the crappie because it simply didn't eat enough bluegills. But the largemouth bass did.

Experiments on pond fertilization accompanying the fish management research proved equally productive. Work conducted at Auburn demonstrated that nitrogen, phosphorus, and potassium increased the amount of algae, microscopic green plants, in the water. Through experiments begun in 1936, the Auburn group demonstrated that production of both algae and fish was increased by pond fertilization.

Unfertilized ponds contained 100 to 200 pounds of fish per acre. But with the addition of a fertilizer, weight of fish in the pond could be increased to a high of 580 pounds per acre. By 1938 the Auburn group had determined a ratio of nitrogen to phosphorus to potassium that was best for fish production. This fertilizer ratio was soon adopted nationwide.

Catfish farm in Texas.

Pond production management begins with proper location, design, and construction. Swingle and his group developed a system of construction and watershed management that used rainwater to fullest advantage. They constructed ponds in a "stair-steps" fashion so that water seeping through the soil from an upland pond would not be lost but captured behind a dam in a pond below. This assures maximum use of available water.

Getting the Word Out

Swingle believed very strongly that an experiment station scientist had a responsibility to let others know what he had learned. Beginning in 1936 with his first article, "Fish Ponds of Alabama," scientific and popular articles and experiment station publications on management of farm ponds attracted considerable interest among fishery managers across the country.

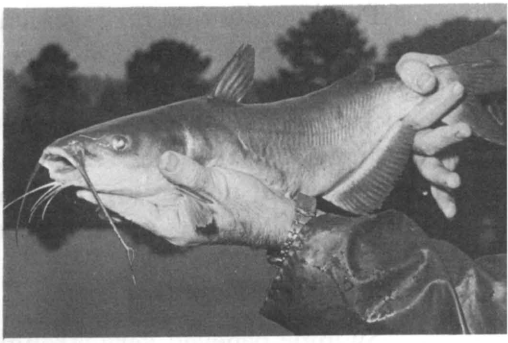
News of the experiments at Auburn spread rapidly. Soon pond owners from all over Alabama were asking Swingle to come try his ideas. He chose a number of larger ponds in widely separated areas of the State. He succeeded in virtually every case in improving the fishing in those "demonstration" ponds. The success stories quickly spread across the South.

Swingle was at his best when using an improvised flannel board technique with a group beside a fish pond, or at a seminar with a group of fellow fishery scientists.

In a short period of approximately six years (1934–40) the fishery group at Auburn developed a system that ultimately would provide millions of hours of recreation for both rural and urban people, and literally tons of high quality protein food as well. Less than 10 years after the first experiment was conducted, the Auburn method was being widely used throughout the United States.

Malaria was an important disease in the South in the late thirties. State health departments noted the increase in the number of ponds in rural areas. Swingle demonstrated that the mosquitoes which carried the disease were absent from well fertilized ponds that were free of marginal weeds and trash.

Swingle realized that an increase in the number of fishing holes would increase the number of fishermen, so he saw the need for educating pond owners on how to raise bait. In 1940 work was begun at Auburn producing red worms for bluegill and golden shiners for bass and crappie. Station publications written on these types of bait production are still in great demand today.



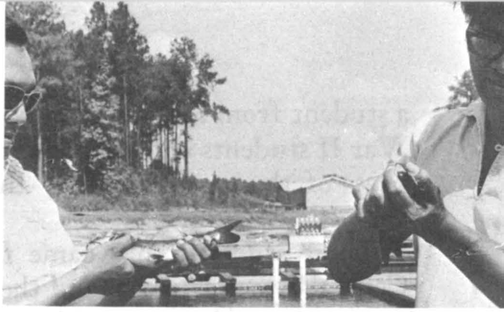
More than 38 million pounds of channel catfish were harvested in 1973. Many of these fish were processed for food; others were stocked in "catch-out" ponds near large cities. Catfish displayed above is from an experiment on selective breeding at Auburn.

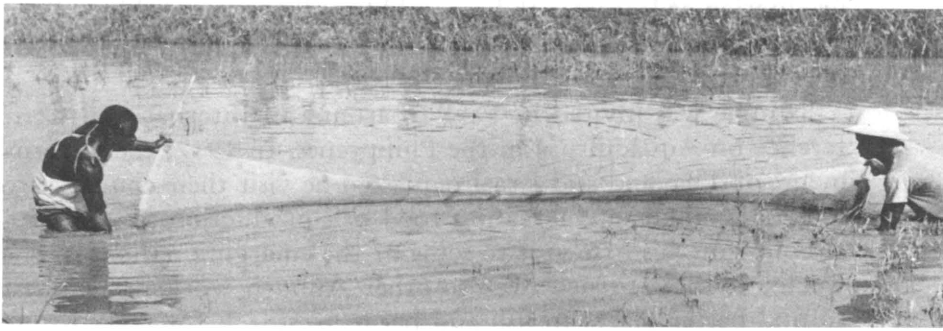
Some of the early experimental work on feeding fish was begun in 1947 when he used poultry and turkey laying mash to feed bluegill in a pond stocked with largemouth bass and bluegill. In 1948 he began experiments on feeding carp. That same year experiments were begun with various feed and grains, as well as mixed feed (cottonseed meal, soybean meal, and dry skim milk combined into a feed for bluegill).

The decision to intensify his research efforts in fish farming was doubtlessly affected by a trip Swingle had made in 1953 through the western part of the United States to study the commercial rainbow trout industry. As a result Swingle spent years studying how to feed fish as livestock are fed.

Channel catfish culture actually began in the mid-1930's when it was found possible to get them to spawn in ponds. A few State and Federal fish hatcheries produced these fish through the years, primarily for stocking in streams and lakes, but little effort was directed toward learning to culture them for food.

Few controlled experiments were conducted on channel catfish farming methods until Swingle began his work in 1949. In 1959, he described procedures for growing channel catfish for food that were to become the basis for much of the channel catfish industry as it is known today.





Rhode Island scientists are helping Puerto Rico fisherman, top left, to improve their techniques. Top right, two graduate students from Philippines check channel catfish at Auburn. Above, pond cultivation of fish in Liberia is benefiting from Auburn expertise. AID helps finance all these activities.

Sporting Proposition

Members of the Auburn group felt that catfish would also make a good sport fish. After producing a large crop of fish in a pond with the use of feeding, they allowed fishermen to harvest them with hook and line.

This research led to development of a sizable sport fish recreation industry. Fishout pond operators purchase large channel catfish from the fish farmer. The fish are stocked into ponds and fishermen are charged for the fish they catch. This type of fishout operation has become very popular, especially around urban centers in the Midwest where relatively little natural fishing is available.

Through the years, research on catfish farming has been intensified at Auburn to cover virtually all facets (breeding, production, nutrition, diseases, marketing, and economics) of this promising aquacultural crop.

The Auburn success story in aquaculture quickly spread across the State, the region, and the country in the late 1930's and early 1940's and it soon spread to other nations as well. In 1943

a student from Mexico came to study with Swingle. After World War II students and research workers began to come from many parts of the world to study the methods of water farming developed at Auburn.

Those students that came from the countries of South and Central America, Asia, and the Near East were not interested in production of largemouth bass and bluegill for sportfishing. They were interested in producing fish for food. In some of their countries sportfishing was virtually unheard of.

Swingle was invited in 1953 to attend an International Conference on Aquaculture in the Philippines. In 1957, the governments of Thailand and Israel requested he visit their countries to suggest methods of increasing food fish production.

Following his first visit to some of the emerging nations of the world, Swingle turned over to other Auburn workers his quest to find better places to fish and began to search for ways to use ponds to feed the world.

In 1967 the U.S. Agency for International Development contracted with Auburn University to provide technical assistance in aquaculture to developing nations of the world. Swingle was Project Director. From 1967 through 1973, he and members of his staff visited more than 20 countries—some of them several times—to train scientists in producing food fish.

As a result of these efforts, aquaculture assistance projects were initiated in Brazil, Panama, El Salvador, the Philippines, and Thailand. Auburn staff members live and work in those countries.

In recognition of the competence in aquaculture and the facilities located at Auburn, the university and USAID established an International Center for Aquaculture at Auburn in 1970. Swingle was named its first director.

In 1934 the Auburn aquacultural scientists began to look for ways to create good fishing holes for Alabama farm families. Forty years later they are seeking better ways of providing fish for the diets of protein-hungry people around the world.

Along the way they virtually revolutionized aquaculture for fun and profit in the United States, and added a new dimension to our understanding of use of the total environment for man's benefit. Theirs is truly a unique Agricultural Experiment Station success story—one that began with a fish pond that wouldn't work.

GOLDEN HARVESTS

The Quiet Revolution in the Apple Orchard

BY R. PAUL LARSEN

Apples came to America during the earliest colonial days and already were the national fruit when the American colonies became a united nation. The tasty fruit spread westward on the new continent even faster than settlers. Apples were spread by the explorers and missionaries, and some Indian tribes planted them around their villages.

John Chapman, the legendary Johnny Appleseed, roamed Ohio and Indiana during the early 19th Century preaching the gospel and planting apples. Marcus Whitman carried apple seeds across the continent on horseback in 1836 and planted them at his mission near Walla Walla, Wash. A sea captain carried an apple seed in his pocket, from England to Fort Vancouver, Wash., in 1826. The resulting tree is still producing apples today!

Nearly every westward-bound wagon train or canal boat carried apple seeds or nursery trees. Americans simply loved apples.

But those cherished apples were unattractive, often disease- and worm-infested fruits that were available for only a few months each fall and winter. Today, we enjoy high quality apples 365 days a year.

What brought about this quiet revolution? It is the result of better varieties and strains . . . improved rootstocks . . . development of highly effective, non-toxic fungicides and insecticides . . . vastly improved orchard culture . . . better fruit handling and packaging . . . new storage techniques . . . and processing to preserve quality and enhance consumer delight.

While tree numbers have declined from 90 million in 1930 to less than 30 million now, orchard sophistication has increased so dramatically that today more apples are produced on one-third the number of trees.

R. Paul Larsen is superintendent and horticulturist of the Washington State University Tree Fruit Research Center at Wenatchee.

Apples are now produced commercially in nearly 40 States, and citizens in all States grow apples for local consumption or ornamental enjoyment. Washington, New York, Michigan, California, Virginia and Pennsylvania produce nearly two-thirds of the total commercial crop of approximately 150 million bushels. The industry has an economic impact of more than $1 billion annually on the Nation's economy.

Although I will briefly mention some of the contributions of others, this chapter is essentially a highly abbreviated story of the contributions of the nation's Agricultural Experiment Stations.

Low quality, mixed fruits from seedling trees were adequate during pioneer times, because most apples were used for cider. But as needs increased for culinary and dessert purposes, better trees were singled out for propagation. The major varieties arose from thousands tested, and step by step the numbers were reduced until today 10 varieties account for 90 percent of national apple production.

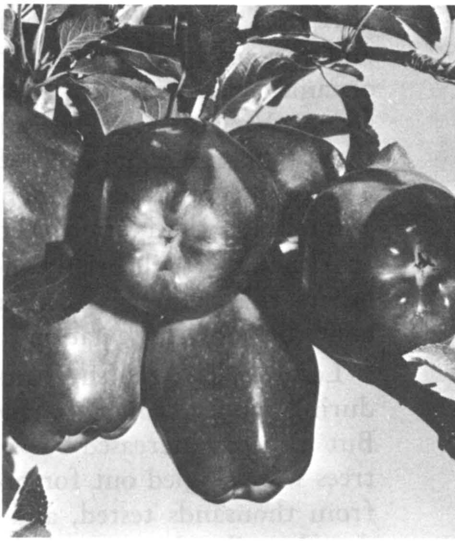
One of the oldest known American varieties was the *Roxbury Russet,* which was growing in Massachusetts about 1649. Two varieties that later gained considerable commercial importance were the *Baldwin,* from Massachusetts, and the *Rhode Island Greening.* Both developed from seedling trees discovered about 1740. *Rhode Island Greening* is still our Number 10 variety in total production.

All of today's top eight varieties were seedling trees hybridized by nature before 1900.

Delicious was found in 1882 in Iowa. *Golden Delicious* started from a seedling on a mountainside farm in West Virginia before 1900. *McIntosh* was discovered in Ontario, Canada in 1811. *Rome Beauty* sprouted in Ohio in 1816. *Jonathan* was first noted in New York in 1826. *York Imperial* was found in the early 1800's in Pennsylvania. *Stayman Winesap* came from a Winesap seed planted in Kansas in 1866. And *Winesap* had an obscure beginning in New Jersey before 1800.

Each has been profoundly affected by research and modern orchard technology. For example, without research McIntosh would have remained of questionable value because of apple scab disease.

Jonathan was an excellent fall apple but couldn't be stored due to Jonathan spot disease. York Imperial was declining until saved by modern processing. Rome Beauty gained a second life when research solved storage scald, a physiological breakdown



Left, harvesting Golden Delicious apples grown on compact trees in Idaho. Above, closeup of Delicious apples. These two varieties lead U.S. production.

which makes it look as if scalding water had been poured on the fruit.

Blond Partner

Improved orchard culture, refrigeration, transportation and marketing have skyrocketed Delicious and its blond partner, Golden Delicious, past the combined production of all other varieties.

None of these varieties is the same as when discovered. They have been improved through science and nature. Bud sports (mutations) have given each variety a cosmetic facelift of brighter and better color than the original.

None has benefited more than Delicious, originally a heavily striped and often dull, light red apple. Over 100 "super red" mutations of Delicious have been identified. Several are compact, spur-type trees which bear earlier and heavier than the old Delicious.

The great popularity of Delicious might have declined had only the common Delicious remained. But because of its original

fine qualities, fortunate mutations and improvements from research, Delicious now accounts for one-third of all apples produced in the United States.

Cortland is the only variety in the U.S. "top 10" that resulted from a controlled breeding program. It originated at the New York Agricultural Experiment Station at Geneva, from a cross made in 1898. It was introduced to the industry in 1915.

Apple breeding programs were started about 1895 and have been conducted by at least 12 State Experiment Stations. Probably the most prolific has been New York, which introduced 52 varieties between 1914 and 1970, a number of which have been widely planted. Other important varieties have been developed by experiment stations in Ohio, Idaho, Minnesota, Indiana, Illinois, New Jersey and by the U.S. Department of Agriculture (USDA).

Many of these introductions have certain desirable and unique qualities, but the present major varieties probably will continue to dominate the national apple industry.

There are several reasons for this. The progeny of a new cross requires 30 to 40 years for evaluation and commercial acceptance. Unlike oranges, bananas, peaches and most other fruits, apples are sold as distinctive varieties.

"Cutting In" Not Easy

Thus a newcomer has great difficulty "cutting in" no matter how fine it may be. But experiment station research has greatly enhanced the productivity and quality of our present varieties through numerous technological advances.

Since apple varieties do not "come true" from seed, a bud or piece of shoot from a tree of the original variety is grafted onto a small tree, known as a rootstock. The rootstock has a major effect on the ultimate tree size, but it has no effect on the size, character or quality of the apples.

Until recently, most varieties were propagated on seedling stocks. The trees became large, up to 30 feet tall with branches spreading 40 feet. Because of their size, only a limited number could be planted on each acre, and individual trees often didn't bear enough fruit to pay production costs until they were eight or ten years old. These types of trees dominated commercial American apple orchards until the 1960's.

Throughout orchard history, particularly in Europe, there has been much interest in rootstocks which would make smaller

trees. These are known as dwarfing rootstocks. Beginning in 1912, the East Malling Research Station in Kent, England, collected and catalogued a series of best rootstocks ranging from very dwarf to standard size trees. These were named EM, after East Malling.

Dwarfs Taking Over

In 1928, the New York State Experiment Station at Geneva obtained a complete collection of EM rootstocks and began an extensive study on propagation, compatibility of varieties, tree size and fruitfulness. The Geneva station distributed over 160,000 dwarfing rootstocks and dwarf trees to individuals and experiment stations in 36 states and Canada between 1938 and 1945. These distributions had much to do with furthering the development of dwarf fruit trees in America.

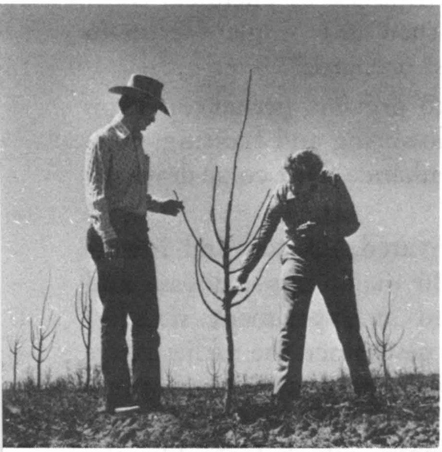
Also, in the 1930's, the East Malling Research Station released hybrid rootstocks that had been developed for insect resistance, better root anchorage, early fruiting and greater production. Additional research programs with these stocks were developed in Michigan, Oregon, Massachusetts, Virginia, Pennsylvania and several other States.

The smaller, semi-dwarf trees became popular with American orchardists because they can be planted close together—as many as 200 to 300 trees to an acre—compared with only 50 to 100 trees per acre for full size trees on standard spacings. The smaller trees also are easier to manage, yet produce more and better quality fruit per acre. Full bearing can be reached in 6 to 8 years after planting, compared to 12 to 15 years (or more) for standard trees.

Although much research is still needed, high density orchards developed through research have resulted in a new apple industry which will be highly valuable to the American apple producer and even more so to the consumer.

Until after World War II, U.S. apple production was characterized by wild fluctuations in annual production. During the 1930's and '40's it was not unusual to have 50 percent variations in crop size. During the past decade the maximum variation between crops has been only 20 percent.

One of the most important reasons for this stabilization was the perfecting of chemicals which reduce excessive crop loads, enhance annual fruit production, protect the trees from disease



Top, high density orchard in Washington State. Above left, Texas horticulturist shows apple grower how young trees are trained for good production. Above right, over-the-row harvester developed at Penn State for use in thin-wall, trellis, hedgerow orchards. Harvester shakes, catches and collects apples in a bulk bin.

and insect damage, and promote good tree health by providing proper nutrients and reducing weed competition.

In its native state, an apple tree struggles to stay alive and at the same time to regenerate its kind through the production of seeds (fruit). An enormous amount of energy is required each growing season to produce fruit, grow new leaves, expand shoots and branches, develop a stronger root system, and build up food reserves for a long winter. At the same time the tree is trying to produce a new set of fruit buds for the next year.

If most of its energies are consumed in producing fruit, the

tree simply cannot manufacture buds for another year's crop—so it bears a crop one year and develops a fruit bud system during the second year.

Chemical Thinning

In the 1940's, following years of research with numerous types of chemicals, horticulturists in several experiment stations (including Indiana, Missouri, New York, Michigan, Massachusetts and Maryland, and USDA) found that hormone-type chemicals such as naphthaleneacetic acid (NAA) would thin apples and greatly improve annual bearing.

These findings led to experiments in all apple producing areas of America and resulted in industry-wide use of chemical thinning, which has contributed more than any single factor to leveling out annual production in most orchards.

Hormone chemicals also are used to prevent preharvest drop of apples in the fall, promote earlier flowering and fruiting, control excessive growth of young trees, enhance fruit color development, and prolong storage life.

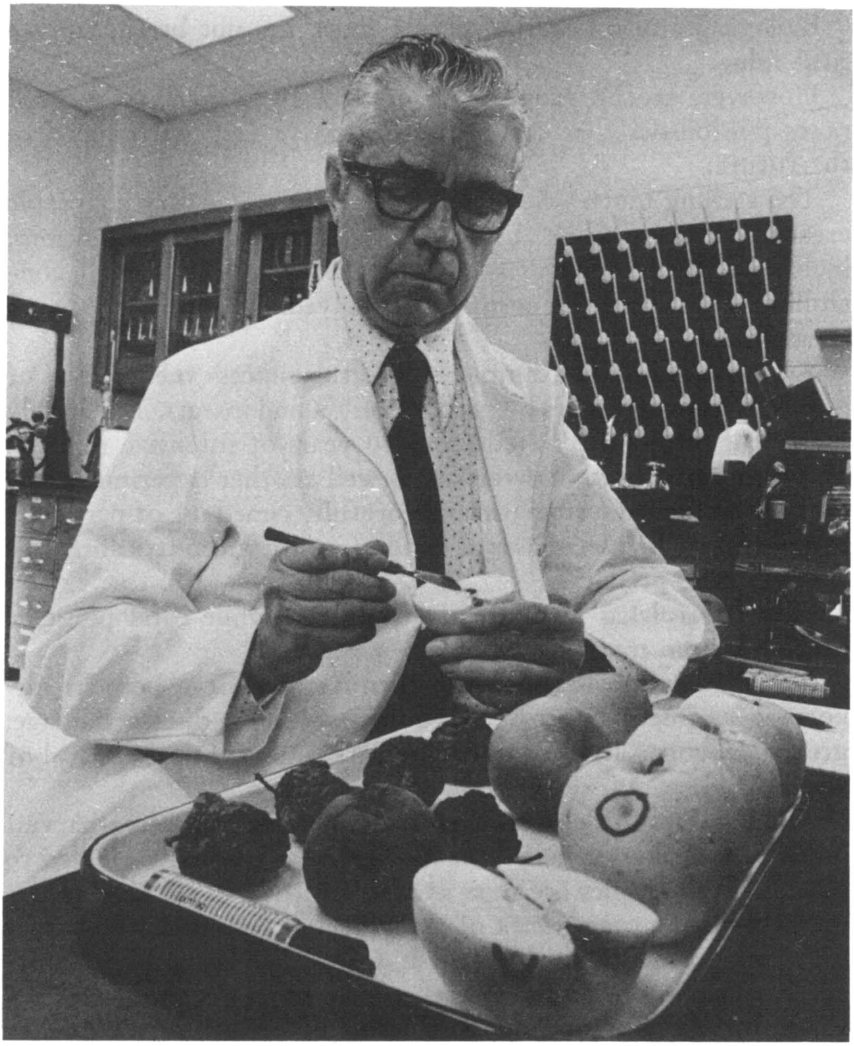
Since the first apple tree was cultivated, diseases and insects have been a constant plague. Over 80 major apple disease and insect problems have been researched at experiment stations. Probably the most troublesome of all pests since the earliest days of orcharding has been the proverbial apple worm—properly known as the codling moth.

Two or more generations of this moth, which looks like the common clothes moth, lay tiny yellow eggs on or near the apple fruits. Larvae (worms) from these eggs eat into the apples, causing the young fruits of early summer to drop, while later brood larvae are often in the mature fruits when they are picked.

Because the damage from this insect was so severe, codling moth research dominated apple investigations in nearly all experiment stations before and after the turn of the century. Entomology and horticulture journals contain thousands of entries on control methods, problems of spray residues, and effects of the sprays on fruit and trees.

"Dynamite Spray"

During the 1930's, over 90 percent of all the apple trees in Washington's experimental orchards at Wenatchee were used in some phase of codling moth control. Forty different materials



Georgia plant pathologist researching apple diseases.

and many mixtures were tried in the control program, most with poor results, and several caused serious injury to the trees. One widely used mixture, called "dynamite spray", contained herring oil and kerosene.

Following World War II, a whole new spectrum of organic chemicals (such as DDT) dramatically improved pest control in apple orchards, and they seldom resulted in damage to the trees. Codling moth control has been further improved with such insecticides as guthion (DDT is no longer used in apple orchards).

Biological control of the codling moth has not been of practical value.

However, recent progress on control by a sterility method raises possibilities that codling moth sprays may be reduced in the future.

The codling moth, like many other insects, is a very adaptable creature. Because of its ability to adjust to changing conditions, including the presence of some insecticides the problem of controlling it will never be permanently solved. Continuing research is essential.

A recent dramatic example of research success was control of injurious mites of apples by predator mites and insects. This highly successful program resulted from 10 years of intensive research by Washington State University, as well as other experiment stations. It includes a systematic and carefully timed use of pesticides to control such insects as the codling moth without killing the friendly mite predators.

Mite control has been greatly improved while total pesticide usage has been markedly reduced.

Many other advances of the chemical age have been as important as insect control—including reducing disease damage, prescribed control of essential nutrients, and chemical control of weeds.

The disasters of deluges of ripe fruit in the fall, after-harvest diseases, and physiological breakdowns have gradually yielded to science. Fresh apples are now available in nearly all U.S. supermarkets during every week of the year and consumers no longer wait anxiously for apple harvest. Controlled atmosphere storage has been more responsible than any other technological advance for the year-around availability of crisp, harvest-quality apples.

Hibernating Like Bears

Controlled atmosphere storage greatly reduces a process known as respiration by putting the apples into a deep sleep, much as bears hibernate. Apples and all living things carry on respiration. Sugars are oxidized (burned) in the presence of oxygen while carbon dioxide, water vapor and heat are produced.

Respiration gradually diminishes crispness, flavor and other qualities in apples. The respiration rate can be reduced by lowering the temperature, reducing the amount of oxygen, or increasing the normal amount of carbon dioxide.

Controlled atmosphere storage includes all three of these. The apples are put in refrigerated, gas-tight rooms where oxygen is maintained at much lower than normal levels, while carbon dioxide levels are higher than normal.

Controlled atmosphere research began in England in the 1920's, but was perfected and developed into full commercial practice in the experiment stations of the United States and Canada.

Over the years, scientists at Cornell University in New York conducted much basic and developmental work in controlled atmosphere storage. Cornell students became research leaders in Washington, Michigan, Virginia and other States.

These and other researchers refined controlled atmosphere storage throughout the United States into a workable and useable commercial practice for the entire apple industry.

Prior to controlled atmosphere storage, the great bulk of the U.S. fresh apple crop had to be marketed between harvest time in the fall and mid-winter or early spring. The late fall and winter markets were usually chaotic and glutted.

The United States now has nearly 30 million bushels of controlled atmosphere storage capacity. This means that about 40 percent of all fresh market apples can be held under ideal storage conditions until late winter, spring or summer—ensuring the year-around apple habit of the American consumer.

But all apples are not eaten fresh. Nearly half of all apples grown are commercially processed. Juice, sauce, slices, pie mixes, frozen concentrate and baby food are processed to provide the greatest possible abundance of low cost apple products.

Concentrate Popular

Many new processes and improved products have been developed in experiment stations and USDA laboratories. One example, concentrated apple juice, which was developed by USDA scientists, has become a popular commodity and is used in jams, jellies and "pop wines."

As apple growing and marketing becomes increasingly complicated, sophisticated and expensive, researchers must find ways to increase mastery over the tree and its environment. This will be done by continually pushing back the frontiers of understanding and technology of manipulation of pests and predators, regulations of growth and fruiting, protection of trees and fruits from freeze injury, complete control of nutrition and moisture, and mechanization of harvesting and handling.

Many hopes for the future are already progressing in experiment station laboratories and orchards. For example:

> Disease organisms, such as scab, may be rendered inoperative by genetic or biochemical mutations.
>
> Rootstocks which are cold hardy and resistant to soil diseases are being developed.
>
> Insecticide usage will be reduced through traps containing female scent attractants (pheromones) which will attract and trap male insects before they can mate.
>
> Antifreeze chemicals will make apple trees and fruit buds less subject to cold injury.
>
> Growth regulating chemicals will insure annual fruiting of mature trees as well as speed up fruit bearing of young trees.
>
> Harvest maturity, fruit color and market life will be enhanced by chemicals superior to any in use today.
>
> Fresh apples will be harvested, handled, stored, packaged and transported to the consumer without the touch of human hands, through the magic of biological, engineering and electronic science.
>
> Low pressure (hypobaric) storage may be the next major step in the constant search to improve apple quality for the consumer.

This is what apple research is all about: assurance that ours and future generations will be able to continue eating that king fruit—the apple.

Consumer's El Dorado Amid Swaying Palms

By A. H. Krezdorn

Most people in the cold and less inviting climates of the United States have envisioned warmer, greener lands with coconut fronds swaying in a soft breeze and the incense of tropical blossoms in the air. The German poet Goethe captured the lure of the subtropics well in the following lines:

Kennst du das Land, wo die Zitronen blühn?
Im
dunkeln
Laub die Gold-Orangen glühn

Loosely interpreted, he asked: "Can you envision a land where the citrus trees bloom? With golden oranges among dark green leaves." Many people have envisioned such lands and have gone there to seek their futures.

Unfortunately, many attracted by exaggerated claims of fortunes to be made in subtropical paradises suffered financial disaster. Even now, oldtimers say, when all alone in a citrus grove on a still, warm, winter day, one can hear the rumble of trains rushing out of the icy north with loads of "snowbirds."

These early agricultural adventurers perhaps would better have identified themselves with lines from Edgar Allan Poe's description of the search for Eldorado, the legendary city of gold.

Florida citrus groves. One at left is being irrigated.

Gaily bedight,
A gallant knight
In sunshine and in shadow
Had journeyed long,
Singing a song,
In search of Eldorado.
But he grew old—
This knight so bold—
And o'er his heart a shadow
Fell, as he found
No spot of ground
That looked like Eldorado.

Neither Poe nor those who sought their fortunes in the subtropics reckoned with the agricultural scientists in the State Experment Stations where Ph.D.'s in white coats in the laboratory and with dusty shoes in the field materialized dreams of a horticultural El Dorado.

The agricultural scientists not only brought profits to growers but they placed orange juice on the Nation's tables at a cost as low as or lower than soft drinks. They made fresh winter vegetables commonplace, and exotic names such as mangoes, avocados, and papayas familiar to many of us.

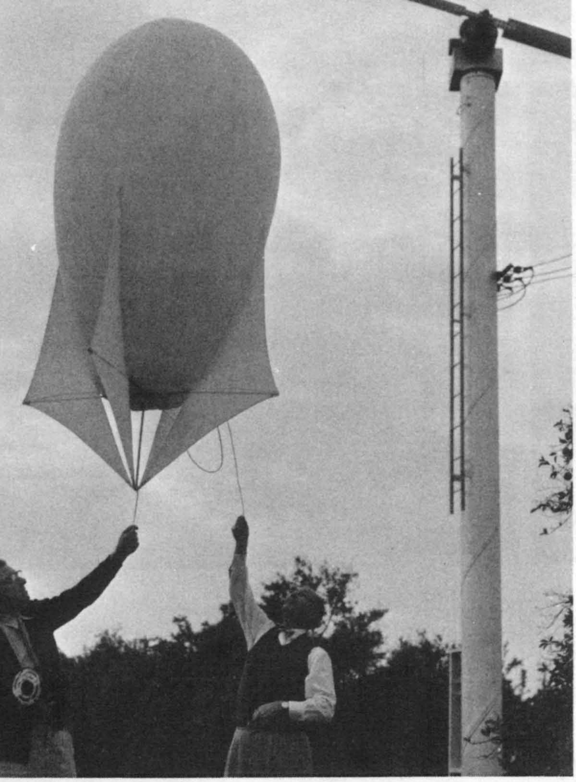
A bit of the tropics has been made available to everyone in the form of exotic foliage plants and cut flowers shipped in ever increasing amounts from the Nation's subtropical areas.

Success has not come easily. Entirely new technologies were necessary, involving pest control, fertilization, irrigation, harvesting, and handling methods. Entomologists, pathologists, soil scientists, engineers, plant breeders, and horticulturists all were on the team.

No crop is more closely associated with subtropics than that group of brightly colored, nutritious fruit species called citrus. Commercial citrus is limited to small subtropical portions of Florida, Texas, Arizona and California. But sweet orange production in Florida alone is greater than the Nation's entire apple production.

Citrus, brought to the new world by Columbus, soon became naturalized on the Florida, peninsula. However, development of commercial citrus is a saga of problems and solutions unsurpassed in agricultural history.

Author A. H. Krezdorn is Chairman, Fruit Crops Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.



Balloon is released over California citrus orchard to carry temperature-measuring instruments aloft. This is part of a study of air temperatures in and above orchards, to learn how much protection growers can depend on from wind machines like one at right.

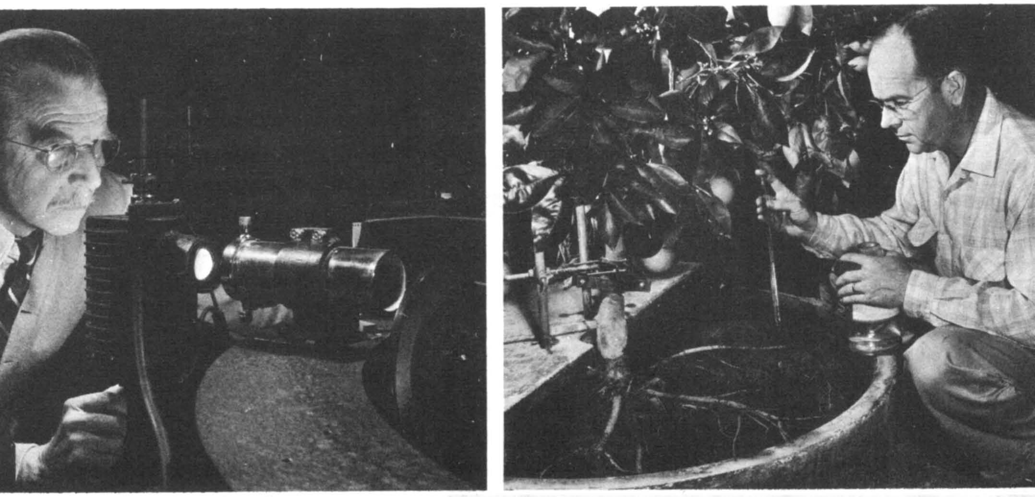
Florida, Texas and California have been rudely battered by wintry blasts that occasionally sweep into citrus areas, freezing fruit and often damaging trees. Research has pointed the way to selection of warm sites and methods to heat the groves.

Wind Machines

On calm, cold nights the physics of heat exchange results in temperatures near the earth being much colder than those aloft, a condition termed a temperature inversion. Research demonstrated that small fires were better than a few large ones, and that warm air aloft could be mixed with colder air nearer the surface through wind machines.

Bit by bit, cultural practices were developed which increased the hardiness of the trees, and led to warmer groves. They often proved the margin of safety on cold nights.

Researchers showed that groves without weeds and cover crops were warmer than groves with them. Trees suffering from certain nutritional deficiencies were found to be unusually susceptible to cold. Oil sprays applied in late summer to control pests induced tenderness to cold, it was learned. And certain rootstocks induced more hardiness than others, researchers discovered.



California researchers at work. Left, studying makeup of a citrus leaf with device that vaporizes the sample in an electric arc. By learning what mineral elements are in leaf, scientist determines how well the tree is taking up nutrients from soil. Right, citrus tree growing in concrete tank containing solutions of minerals. Scientist adds measured amount of mineral to solution so effect of mineral on tree's health can be learned.

The deep sandy soils of central Florida are unique in their lack of mineral elements. California and Texas also have had many problems involving mineral nutrition despite their fertile soils. Mineral nutrition research has been so thorough that major nutritional problems belong to the past.

Commercial citrus trees are two-parted as the result of budding a desired variety onto some other kind of citrus (the rootstock). Florida researchers established the advantages of using rough lemon rootstock, which penetrates to depths of over 20 feet, on the droughty sands of central Florida. Texas researchers determined the value of sour orange rootstock in tolerating soil diseases and saline water. California research demonstrated a closely related citrus relative and hybrids used as rootstocks would overcome the problem of replanting on old citrus soils.

Pest-related problems were myriad and some of the control measures established are classics. Citrus canker, introduced from Japan into the Gulf Coast area, was completely eliminated from the North American continent through measures developed by research and carried out by regulatory agencies.

The Mediterrean fruit fly was accidentally introduced, and eliminated through special baits distributed by aircraft.

Left, growing hundreds of plants in test tubes, California scientist knows exactly what each tiny plant will look like when mature. Known as tissue culture, propagation method consists of selecting precise bits of tissue and growing them in carefully formulated nutrient medium. Thousands of plants, all identical to parent, get off to disease-free start. Tissue culture is particularly valuable to flower growers. Right, asparagus plantlets grown using tissue culture technique.

Scale insects in California once were controlled by tenting each citrus tree and using dangerous cyanide gas to kill the pests. This gave way to oil sprays that are safe for both plants and humans. In more recent years, researchers introduced tiny wasps which virtually eliminated the two most important scale insects from the Florida peninsula. California long has used ladybird beetles and other biological control measures.

Virus and virus-like diseases have plagued citrus growers. A scientist in California recently developed a most imaginative method of obtaining virus-free buds. Working with the knowledge that citrus virus diseases were carried only in the vascular tissue, the tissue through which water and food moves in the

plant, he reasoned there would be no viruses in a few cells at the growing points of plants. This is a region of cell division where there is no vascular tissue.

He then micro-grafted a tiny piece of the disease free growing point onto very small seedlings growing on an artificial medium in test tubes. This delicate operation required development of surgical skills with which to make the minute graft, and completely antiseptic conditions.

The tiny plants were ultimately transferred into soil where they grew and may serve as a source of buds for producing commercial trees free of bud-transmitted viruses.

Researchers continuously strive to reduce the use of expensive agricultural pesticides, which at times may be environmental hazards. Use of biological barriers to prevent the spread of a tropical nematode is an example.

This nematode, a small worm-like creature, is mobile, infesting increasingly large areas by moving slowly outward from points of infection.

Chemical barriers—wide, plant-free strips of periodically fumigated soil around infected areas—were effective but expensive.

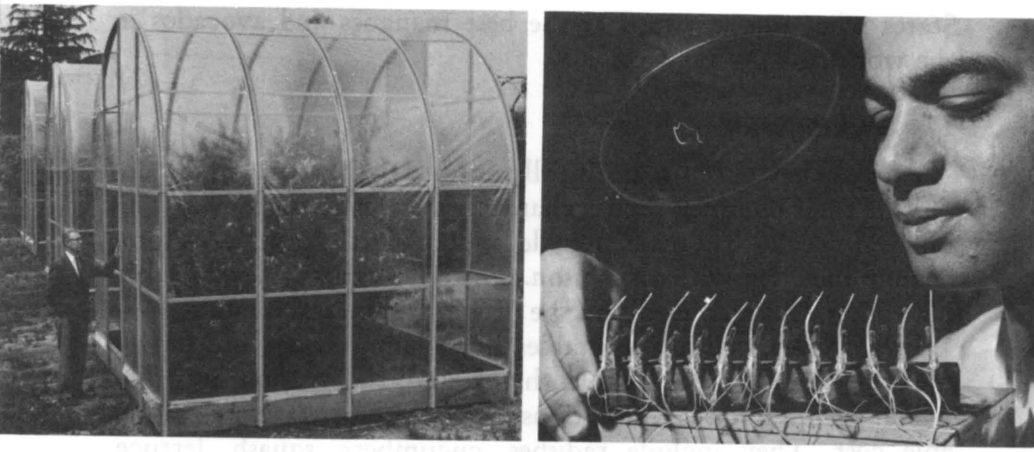
A citrus rootstock was found in which the nematode could not live. Researchers reasoned they could contain the nematode in small pockets of infection by surrounding infested areas with buffer zones of trees on these rootstocks. The experiment failed at first because citrus roots from infected and unifected sides grew through several rows of the barrier. This was counteracted by periodically severing the roots between the buffer trees and the infected ones.

Giant Saws Trim Trees

Citrus trees are long-lived and grow very large. Trees ultimately become crowded and decline. Movement of equipment in the orchards gets difficult, and harvesting expensive. Large, mechanical pruning equipment consisting of giant saws on rotating arms has been developed to ease this problem. Some saws are mounted vertically to cut off the sides of trees. In other cases the saws are mounted horizontally to cut off tree tops, sometimes slicing away as much as the top 15 feet of the tree.

These mechanical behemoths moving through a grove with gyrating arms and humming circular saws are an impressive sight.

Even determining when a citrus fruit is mature has required



Left, to learn effects of smog on citrus trees, California scientists built these plastic houses around trees in a commercial orchard. Some trees get ordinary air, others get filtered air. Right, Egyptian graduate student in California used oat sprouts as test plants to verify finding of new plant hormone in citrus fruit. Applying a growth-stimulating chemical or hormone to one side of each tip makes that side grow faster, causing sprout to bend over. Sprout on extreme right was untreated.

much research. Grapefruit, for example, can be harvested from the same tree from October through June and it is a matter of opinion as to when it becomes palatable.

State laws were established to regulate the time of citrus harvest, based on research which showed a relationship between palatability and the levels of juice, sugar and acid in the fruit.

Consumers long have assumed that sweet oranges have an orange color. However, sweet oranges do not color well in warm areas, attaining the typical golden color only after cold weather has destroyed green pigments in the peel. The change in color bears little relation to quality. Researchers ultimately developed a means of accelerating the natural process by treating this fruit with minute quantities of ethylene gas to destroy the green pigment and enhance the orange color, without affecting quality.

Fruit species more tender to cold than citrus—such as mangoes, avocados, papayas, guavas and macadamia nuts—have been introduced into subtropical areas and some have reached the status of commercial crops. The technology of producing these crops has not received the benefits of as much research as was devoted to citrus. But marked achievements have been attained.

Ferreting out improved varieties from thousands of chance seedlings obtained from various sources has given the United

States what many regard as the best mangoes and avocados in the world.

The Sexy Papayas

Papayas have been scientifically studied in Hawaii, where details of their complex sexual characteristics were described. This unusual species has male, female and bisexual forms and some change their sex with the season. The Solo variety, developed in Hawaii, is a hermaphroditic type of good shape and quality.

Fresh, crisp, winter vegetables in dazzling array, are only a portion of the fare available throughout the Nation at prices which permit a varied, nutritious diet at a comparatively reasonable cost. They include radishes, cucumbers, squash, lettuce, celery, carrots, beans, tomatoes, peppers, melons and sweet corn. The era in which the basic vegetables for winter meals consisted of dried beans, canned food and stored Irish potatoes is only a distant memory.

Sweet corn production in the subtropics is a fascinating example of man's ability to produce crops where they were not originally adapted.

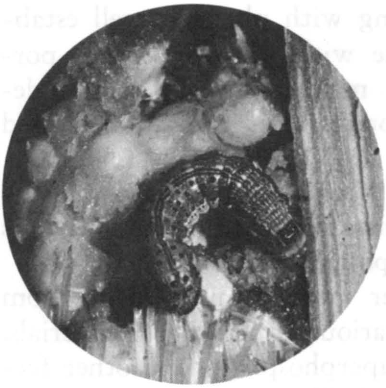
The corn earworm once ruined every ear of corn grown in subtropical areas.

Researchers found the earworm could be controlled by carefully applying pesticides. Initial control measures were crude. Painstaking research, however, developed chemical control measures that are extremely effective, and safe.

Then a second unsuspected pest, corn blight fungus, threatened to reduce the production of sweet corn to a point of unprofitability. Fungicides were found that would control this disease. Moreover, scientists developed a system for determining at any point in development of the crop when the fungus has become sufficiently severe to affect the yield and quality of corn at harvest. This greatly reduces the spray applications needed.

A recent exciting breakthrough demonstrates the great potential of scientific breeding. Sweet corn must be thrust into cold water immediately after harvest to prevent the sugars, which make it sweet, from being converted to starch. New varieties are being released that do not contain the enzyme which converts sugar to starch. This means harvesting and handling procedures will be simpler and the consumer will be assured a high quality product.

Development of a tomato industry in the subtropics is a no less



A corn earworm at work.

intriguing story. The tomato originated in the American tropics but superior varieties, not adapted to the tropics and subtropics, were developed in temperate zones. Thus, commercial tomato production had to be "introduced" from the temperature zones and new varieties and cultural practices developed for the subtropics.

Plant pathologists and entomologists developed chemical control measures for the army of pests that faced subtropical tomato producers, but the researcher is never satisfied with expensive chemical control. Plant breeders gradually have made impressive changes in pest resistance and climatic adaptability through plant breeding.

The Southern Tomato Exchange Program (STEP) is one of the best examples of cooperative programs between state and Federal research organizations. Tomato breeders of these organizations have voluntarily organized a cooperative research effort in which breeding lines are exchanged and a regional research program in effect conducted. This exchange of data has greatly accelerated improvement of tomato varieties.

Innovative changes in cultural practices based on research also have helped maintain productive, competitive tomato industries in subtropical regions.

Good examples are the use of plastic mulch to prevent loss of fertilizers and to control weeds, and the use of plug-mix seedlings. The latter refers to incorporating crop seeds and water into a scientifically blended growing medium. This is then precision-placed in the field with machines. Thousands of acres of tomatoes and peppers now are planted that way.

Ornamental horticulture is the new boy on the block. The United States is well into an urban age and ornamental horticulture is taking its rightful place.

The therapeutic value of working with plants is well established. Mankind's need to associate with growing things portends an increasing use of plant material in the home, development of parks and recreational areas, and an increased emphasis on landscaping.

Production of foliage plants has increased astonishingly in the past decade, and the need to ship these plants to distant markets has brought the use of lightweight potting mixes.

Growers initially threw together various mixes made from wood shavings, peat moss, and various other inert materials. These materials were mixed with superphosphate, and other fertilizer elements were added as needed. The mixture worked well for many plants but some species developed tipburn and dead areas in the leaves that made them unsightly.

Sensitivity to Fluorine

Scientific detective work has demonstrated that some plants are extremely sensitive to fluorine, showing varying symptoms at concentrations as low as .01 parts per million (ppm) in the rooting mixture. Peat moss was found commonly to contain 4 ppm of fluorine, and superphosphate from 10,000 ppm to 20,000 ppm of fluorine.

Addition of calcium counteracted the effect of the fluorine in the peat moss but the relatively large concentration of fluorine in superphosphate necessitated the use of safer phosphorus sources. Also, the housewife is forewarned that drinking water that has been fluorinated to prevent tooth decay is unsatisfactory for watering certain foliage plants.

Diseases are major problems. Many ornamental plants are propagated by asexual or vegetative means, such as through the use of bulbs or stem cuttings. These procedures have certain advantages, but many virus and bacterial diseases are transmitted in this manner. Recently caladiums, which are heavily infected with virus diseases, have been produced that are virus-free These experimental plants have grown astonishingly fast and produced larger, more beautiful leaves.

Decline of field-grown plants when transferred to homes and buildings has been an intriguing problem. Researchers have found there actually are two problems.

Some plants grown in full sun will shed many leaves when placed in buildings with under 2,000 foot candles of available light. Also, plants grown under field conditions are heavily fertilized because they grow very rapidly and form many leaves.

Garden fans on vacation trips to St. Thomas in the U.S. Virgin Islands can tour the agricultural station at Dorothea, and buy ornamental plants. Among plants available are hibiscus and crotons. You can take plants back to the mainland U.S. provided they are free of soil, and have been inspected and certified by the USDA office at Charlotte Amalie airport.

Such plants placed in shade grow less vigorously and use much less fertilizer. The excessive fertilizer becomes toxic and damages the plant.

These problems have been corrected by placing the sun-grown plants under shade for five to six weeks before shipment and by washing out much of the fertilizer with heavy applications of water.

Successful breeding and release of varieties of anthuriums in Hawaii and gladiola in Florida portend an era of exciting new ornamental varieties.

Grass for Lawns, Golf

The breeding of new grasses for home lawns and heavily used areas such as golf courses is progressing. Floratam, a St. Augustine selection developed in Florida, not only has proved resistant to St. Augustine—grass decline, called the SAD virus, but to chinch bugs as well. It is equal or superior to the common St. Augustine grass in its tolerance to downy mildew and gray leaf spot diseases.

Researchers who develop lawn grasses carefully test them under all sorts of conditions to make certain they have no weakness which will cause problems not encountered with the grass that they replace.

Despite the litany of successes achieved by State Agricultural Experiment Stations, the battle to maintain a productive agriculture at reasonable cost to the consumer must be intensified. Nature is harsh, cunning, and never completely dominated.

Plants, animals, insects, diseases and nematodes continuously change through both sexual processes and mutation. Pests may suddenly develop ability to attack a plant which was once resistant to or tolerant of them. Mites and insects may rapidly develop resistance to pesticides which once offered this control.

An insect-transmitted disease currently is killing huge numbers of coconut palms in the tropics and also coconut palms used in the subtropics as ornamentals. There is evidence the disease is spreading to other species of ornamental palms as well. Researchers are already attacking this problem with their technological weapons.

Mechanically harvesting many crops will become a necessity, and this problem is as challenging as any previously faced.

Assuring the safety and nutritive value of foods used by the consumer has been accentuated, and rightfully so, in the last decade. Many chemicals formerly used in controlling pests no longer are available, and new ones must be carefully screened at great expense.

Urbanization and population increases are taking a toll of the best agricultural land.

On the bright side, scientists now have computers and an impressive array of new instruments with which to solve the mysteries of plants. Banks of knowledge developed over the years are at their disposal. Thus, those Ph. D.'s with dusty shoes will prevent the subtropical, horticultural El Dorados so painstakingly produced from becoming ghost towns.

Grass—the Food Factory That Also Fights Drought

By R. A. Moore and John L. Pates

Grass. Like the base of your living room carpet, grasslands go virtually unnoticed by most of us. Yet grass, perhaps the most humble family of the plant world, has served as a foundation for the food and fiber needs of this planet.

Grass, in a year like 1974 when a general drought prevailed over much of the Central and Northern Plains, may mean the difference between steak on the table, even though the price may be higher, and no steak at all.

"Grass is the forgiveness of Nature—her constant benediction. . ." wrote a U.S. Senator from one of the Plains States (Kansas) in 1880. Grasses, most of which are close relatives of the plants that grow in the green areas of our parks and in your own backyard, have been studied by historians and ecologists, fought over by farmers and ranchers, and have provided inspiration for philosophers and poets.

To the researcher the grass plant is an awesome and marvelous thing. Each contains a factory capable of manufacturing food . . . a feat not yet accomplished by man.

Grassland exists in every State and is important to each. We confine our comments to the greater grassland areas of mid-America. Picture if you can a line running down the center of our continental United States, with the Corn Belt to the east and the Great Plains on the west. The overlap areas encompass these grasslands.

Some areas are well suited to grass. Some areas also are suited to other crops. The grassland acreage expands in a rather pulsating fashion, depending on the price of the various crops with which grass must compete. When wheat prices soar, the grassland acreage shrinks. When the price of an alternate crop drops, the grassland acreage grows. Sometimes these former grasslands are

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simply abandoned. It then may take years for the grass to return.

Fortunately, economics is not the only consideration on which the decision to keep land in grass is based.

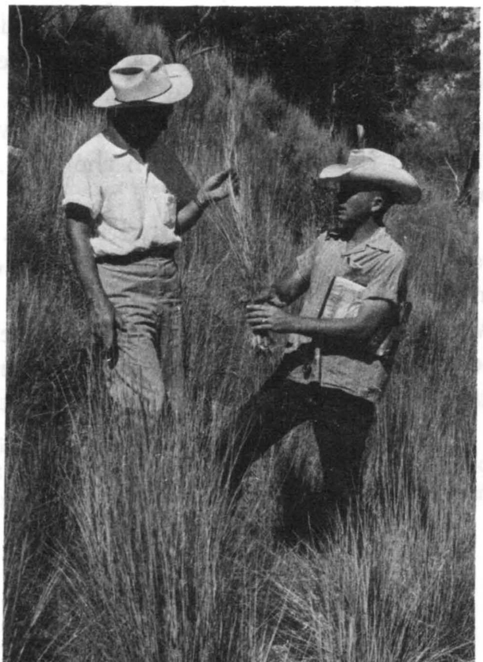
As you drive from east to west, notice that the deep black soils are usually planted to more intensive crops such as corn, soybeans and grain crops. Tall native grasses such as big bluestem and Indiangrass will be familiar grass species in these areas. Here settlers plowed under grass and removed trees to clear the land for farming in homesteading days.

Intermediate or medium height grasses—such as little bluestem and western wheatgrass—will be found growing on brown and chestnut colored soils. This is the beginning of the Plains area. Short grasses like gramagrass and buffalograss are natives of the semi-arid and arid lands and the lightest colored soils.

Settlers brought with them crude implements to break the sod and till the land. Hardships were common. Drought, fire, severe winters all challenged the talents of the farmer. Through trial and error, settlers learned what they could do to make the land productive.

Settlers didn't call this trial and error "research", but that is exactly what it was. Today, largely because of more sophisticated methods of research, grass is recognized as an important crop. Farmers learned that in the more arid parts of the country, grass was the one crop you could usually depend on . . . and even that needs moisture.

Little bluestem grass on a Texas ranch.



Dust Bowl Era

The dust bowl years of the 1930's demonstrated the folly of the plowman and put the need for better methods of soil conservation into much sharper focus for both the researcher and the farmer.

Settlers in the Dakotas, Iowa, and down through Texas and Oklahoma who needed clouds filled with rain for their crops saw clouds of dust instead. One of the first tasks of researchers at experiment stations throughout the Great Plains was to figure out ways of turning clouds of dust back to a sea of grass again.

Fortunately, experiment station researchers had already brought some new and soon to be important grass varieties into this country.

At the turn of the century, men like N. E. Hansen of the South Dakota Agricultural Experiment Station, working on behalf of the U. S. Department of Agriculture (USDA), observed something called "crested wheatgrass" at the Valuiki Experiment Station located 150 miles north of Stalingrad, Russia.

He observed that the grass was doing well in a very harsh climate, and noted that this might be a very valuable plant to the Plains area of America. History proved his observation to be prophetic indeed.

In about 1906 seed was distributed to various States in the Great Plains area. But the emphasis on grass research was not yet apparent in most parts of the country. The demand was for wheat.

Wheat prices soared. Wheat grows well on grasslands when moisture is available. Instead of grasslands being improved, large tracts were simply broken up for wheat between 1905 and 1920.

When the dry years of the 1930's arrived, the role of grass in stablizing the dry Plains became evident. Fortunately, the introductions of crested wheatgrass made by Hansen and other Agricultural Experiment Station researchers had survived. Commercial seed was actually available by 1929.

Historians now maintain that no other forage grass filled such an important place in our revegetation program. Crested wheatgrass, a hearty perennial, could resist drought and withstand weed competition. It also made excellent forage for cattle. (A perennial grass is one that does not have to be seeded every year.)

And had it not been for a grass research program conducted by the Agricultural Experiment Stations over the years, beefsteak might be as rare in the United States as it is in many other countries of the world today.

The real value of crested wheatgrass was realized through the work of George Rogler, of the Northern Great Plains Field Station at Mandan, N.D. He understood both plant breeding and grass management and developed the superior variety, Nordan. It performed well on the abandoned wheat land and produced a good yield of high quality seed.

Rogler, working for USDA's Agricultural Research Service, achieved what Hansen had envisioned. This illustrates the kind of teamwork that has usually existed between State and Federal agricultural research agencies.

Another example of teamwork between such agencies involves the Soil Conservation Service (SCS). This USDA agency has been working at the business of grass selection and range improvement programs since it was established. Joint release programs between SCS and Agricultural Experiment Stations exist in a number of States and the joint release of a number of grass and shrub selections has resulted.

Since these early beginnings research stations in Minnesota, Missouri and many other States have picked up on various aspects of grass and grassland improvement research.

Hansen, although a horticulturist by profession, was a keen observer of all types of plant life. He was interested in any plant life that looked like it might survive and add to the satisfaction of living in the Northern Plains area.

"Cossack" Alfalfa

Among the plant specimens he brought back with him from Russia was something called "Cossack" alfalfa. He also secured "wild" alfalfa plants. Planted in several States, they were all but forgotten. War and the need for human food from cereal crops replaced interest in plants which would support livestock production.

Cossack is still grown on many farms and ranches because it tolerates cold weather and some drought.

Alfalfa and grass make an excellent combination in cropping for a number of reasons. Nitrogen, a plant food needed by all grasses, is produced naturally by alfalfa and other legume crops. When a steer or cow eats too much of a fast growing alfalfa crop, however, it frequently becomes a victim of "alfalfa bloat" caused from gas that is manufactured from alfalfa as it goes through the digestive process.

Hansen (far left) in Russia collecting various types of plant specimens he thought might be useful in Great Plains agriculture.

The logical solution would be to plant the two crops together. However, growth habits of most grass and alfalfa varieties are entirely different. But the "wild" alfalfas have a growing habit similar to grass and they did survive in pastures.

So researchers worked to domesticate the wild alfalfa. Varieties were eventually developed that were called "pasture" types.

Smooth bromegrass is another good example of an introduced grass variety that has provided excellent grazing in Corn Belt pastures.

This species was first introduced into California in 1884, probably from Hungary. It was grown in the Midwest by 1890. Hansen also brought this grass to the United States from Russia.

Frequently mixed with alfalfa, smooth bromegrass grows early in the spring, goes somewhat dormant in the summer, and provides good grazing again in the fall. The spreading root system provides an excellent ground cover for erosion control.

Another European native is orchardgrass, which flourishes in the richer soils that stretch from the Atlantic Coast to eastern Kansas. It was first grown in Virginia and received its name because it grows well in shaded areas.

At one time orchardgrass and bromegrass were considered in about the same terms as ham and eggs. They just seemed to belong together.

But researchers with knowledge of grass management found that this theory did not hold. A research project led by Merl Teel, then at Purdue University, revealed that some grasses respond well to early grazing while others go dormant under early graz-

ing. He discovered that bromegrass and orchardgrass yielded much more forage when grown separately than each did when grown together.

Birdsfoot trefoil is another legume that became important to the grasslands area of the United States after experiment station researchers identified its properties and learned something about the management of it. A prominent figure in this research was H. D. Hughes of Iowa State University.

Birdsfoot trefoil, a native of the Old World, was introduced into the United States at about the turn of the century. It resembles alfalfa but does not cause bloat in livestock.

Seed harvesting was especially difficult because of the uneven ripening habit of trefoil. Hughes' research minimized this problem and contributed important information to management—including stand establishment and seed harvesting procedures.

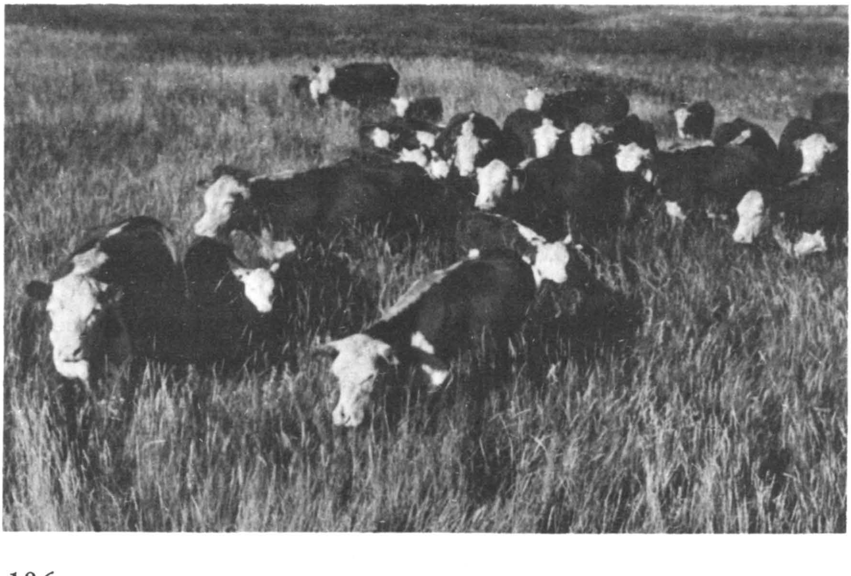
Cool and Warm Season Types

Cool season grasses grow best in the Northern Plains when moisture is most prevalent. They go dormant during midsummer.

In later years considerable research has been devoted to developing warm season grasses suitable for use in both northern and southern areas. One example is sudangrass, which has been a popular supplemental pasture in the Corn Belt.

L. C. Newell, USDA scientist at the University of Nebraska,

Cattle on an intermediate wheat grass pasture in South Dakota.



has been very successful in developing superior varieties of warm season species, and James Ross at the South Dakota station has made a significant contribution with his development of Summer "switchgrass." His cool season "Oahe" intermediate wheatgrass is also known throughout the Plains and westward.

Native grasses and tame grasses have many of the same growth characteristics. But management of native grassland is more complicated because several species are usually found growing together and often in areas where moisture is short and soils are poor.

Scientists do not agree on the best method of taking care of native pastures. Some feel the first consideration is to properly manipulate the grazing animal.

Interestingly enough, most animals are "selective grazers." They will eat certain plants and leave others if given the opportunity. Some plants then become unpalatable and animals will not graze them at all. Even the nomadic tribesmen of an earlier day recognized the merits of moving animals from one range to another to allow time for grass to recover.

E. L. Dyksterhuis of USDA's Soil Conservation Service devoted many research years to range improvement. His philosophy, simply stated, is that the environment should not be changed, that animals must be managed in such a way that key species of grass are protected. Another theory is that environment can and should be modified and production can be increased through fertilization, weed control, reseeding, and mechanical tillage.

Because of the great diversity in soils, grasses, and climatic conditions throughout our country, both points of view have proved appropriate under certain circumstances.

Discovering Green Gold

Research at Agricultural Experiment Stations has now clearly demonstrated that overgrazed and neglected pastures can be turned into highly productive areas, that ranchers accustomed to getting two or three months of grazing time from a pasture could actually stretch the grazing time out to six or even up to nine months. To some ranchers this has virtually meant "Green Gold." To the consumer it has kept meat on the table at prices that are among the lowest found anywhere in the world today.

Land that didn't yield enough hay or pasture to cover the tax payments has become valuable because of grassland research projects.

Getting grass started to grow is often difficult. In many cases

the soil or terrain is unsuitable for using most kinds of tillage equipment. Grass is also unpredictable in terms of seed production. This has discouraged many farmers and ranchers from trying to rejuvenate pasture areas.

Research at South Dakota State University and at other stations has demonstrated that the type of seeding implement used and seedbed preparation are key factors in getting grasses established or reestablished.

Research also shows that seedbed preparation and depth of planting is much more critical for the tiny grass seeds than for most crops. Planting depth usually must be between a quarter and a half inch. And if the seedbed is not packed firmly, the stand will be significantly reduced, even if all other conditions are proper. The same conditions must be met to establish a new lawn.

Early spring or late fall is the best time to seed cool season grasses. Warm season grasses grow best and should be planted during early summer or late spring.

More difficult is grass establishment on areas not suited for plowing and conventional methods of seeding.

Agricultural research throughout the Great Plains shows that several implements can substitute for the plow. Those that leave a mulch on the surface are especially good. Where tillage is possible, some studies show it helps to plant some other crop for two or three years before seeding grass.

Soil erosion is a problem on rolling land. Various methods of farming slopes have been researched.

Sod seeding or interseeding into established pastures has been successful. The creeping alfalfa varieties (referred to earlier in this chapter) have been very useful here.

When stress such as overgrazing or drought is placed upon a pasture, the most desirable plants may be replaced by weeds, commonly defined as "plants out of place." A desirable plant in one area may be undesirable in another. Any plant would be considered a weed in a pure stand of grass kept for seed production, for example. Yet several types of plants are desirable in a mixed species pasture.

Through research and experience, ranchers have learned also that some plants or weeds can be removed or controlled by turning livestock into a pasture at certain times. Mowing pastures to eliminate weed seed production is very effective and has been highly recommended.

Weeds that spread via underground roots are called perennial.

These are difficult to control. In some cases selective and non-selective herbicides are the only choices for weed control. These are usually limited to use on small areas that contain a very difficult weed problem.

Agricultural Experiment Stations throughout the country have research projects that constantly evaluate weed control techniques and the effects of various types of chemicals used for both weed and insect control.

Insects That Can't Bug You

Methods for biological control of weeds are being explored at several stations, including both Dakotas. This is an especially challenging area for researchers. The entomologist, for instance, must find an insect that selects only the undesirable plant. It cannot be one that would attack a desirable plant in the area after the weed is controlled.

Research has demonstrated that pasture fertilization allows earlier grazing in the spring and higher pasture yields.

Early grazing means the livestock grower may not have to buy expensive supplements during the spring months.

Pasture and range fertility work conducted at nearly all Agricultural Experiment Stations shows that each grass type responds differently to fertilizer treatment. The amount applied and the time applied are very important. In fact, fertilization may encourage one type of grass and discourage another.

Research has demonstrated the wisdom of applying only the amount of fertilizer needed and the type needed. You can have soil tested at most experiment stations free or for a small fee. A soil test includes recommendations concerning the type and amount of fertilizer needed. These can supplement animal manures if they are available.

While much has been learned about pasture establishment, grazing principles, and management in general, some of the most impressive developments in research have concerned forage harvesting.

Several machine companies have become partners with experiment station agricultural engineers in the search for machinery designs that could make grass planting and hay handling easier and more automated.

The importance of fast, efficient hay handling cannot be overemphasized.

Research has shown that the leaves of pasture plants may contain 50 percent of the weight and 90 percent of the protein or plant food value. The object is to harvest the crop and store it in such a way that losses in food value are held to a minimum.

Because it is now difficult to hire extra farm hands during the hay harvesting season, machinery that can allow one man to handle the haymaking operation alone is much in demand. Efficient crop handling has kept food prices relatively low over the years.

A large joint North Central research project currently is in progress. Several states have joined forces to work together on evaluating haying techniques and systems.

Grassland research along with other types of agricultural research has been coordinated on a regional, national, and even international basis. While research has solved many problems it also has uncovered many new and challenging ones.

This type of research effort has benefited the urban consumer. It has helped provide a food supply unequalled anywhere in the world, and has done so without destroying the environment. In many cases the environment has been improved.

The Bible tells us that some areas of the Old World once produced an abundance of agricultural products. Many of these areas are almost desolate today. Agricultural research from the United States is being applied in parts of these areas to help make them productive again.

Drought and other types of crop-destroying phenomena will continue to plague agriculture everywhere. Research projects have helped man find ways of coping with these problems. For example, even though weather records show that the drought experienced in some areas of the Plains during the early 1970's rivals that experienced in the 1930's (in terms of the number of consecutive days without recorded moisture), the total food and fiber supply of the Nation has been maintained well enough to avoid the severe shortages of meat and crops known throughout most of the world.

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Redwoods to "Popple"— Aladdins in the Forests

By Frank H. Kaufert

In 1925 a young forester was measuring a plot of aspen, the weed tree that developed on millions of acres of Lake States forest lands after logging and land-clearing fires. A local settler watched him for a time and then exclaimed: "Why are you measurin' de popple, what do you think that you and those other city slickers that have been countin' and measurin' here all summer can do with that worthless bresh".

Brush indeed. In the 50 years since that incident popple or aspen has become the miracle tree and is used for dozens of products, from lumber to paper. This phenomenon has been true for many species in other parts of the country, mainly because of research and development.

This research extends literally "from the cradle to the grave". It ranges from the minute seeds of some of our mightiest trees, such as those of the 368-foot Coast redwoods, seeds that are no larger than some grass seeds, to the preservation of the gnarled Bristlecone Pine, some of which may be over 4,000 years old.

It covers the reproduction, growth and management of our close to 100 commercial tree species—evergreen and deciduous, hardwoods and softwoods, conifers and broadleaved, and all of the related products and values resulting from forest land management.

Let's start our story with aerial photogrammetry and remote sensing, informational tools that serve the forest land managers and users in dozens of ways. One of the earliest applications of aerial photos was in the national forest survey, the first of which was made by the U. S. Forest Service in 1931.

To a group of young foresters sloshing and wading through

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southern bayous and cypress-tupelo swamps, the provision of aerial photos by the Corps of Engineers was an historic occasion, even though the photos were made for flood control and not forest survey purposes. Now we could see where we were going, what we could and could not avoid, where the timber was that we were surveying—and what it was.

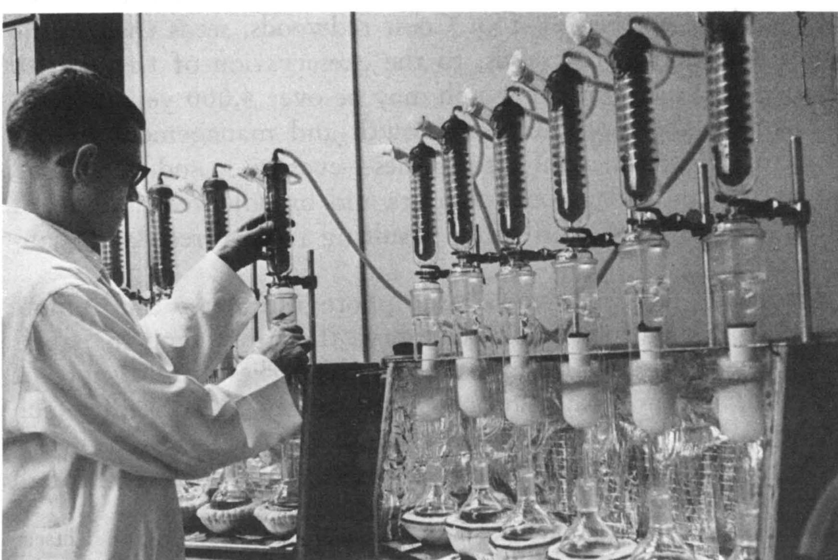
Boon to Fire Fighters

Today's fire-fighting crew boss on a forest fire that has filled a western forested valley with a huge smoke layer needs to know where the front of the fire is. How does he find out? He studies aerial photos taken with infrared film. This heat sensitive film registers the front, the hot spots, through several thousand feet of dense smoke.

Research is underway with the same or similar films to census big game. Other uses of aerial photos include detection of forest tree diseases and insect epidemics, locating logging roads, mapping of timber types and estimating timber volume, watershed mapping, and determining sites for manufacturing plants.

Low altitude 35mm infrared aerial photography is being used to analyze trends in rangeland vegetation and to monitor wild-

Lab work on infection by rot, at Southern Forestry Experiment Station in Mississippi. Forest Service and State scientists cooperate in work at USDA regional research stations like this across country.



life habitat changes, waterfowl nesting and feeding areas, and conditions of structures such as stockpond dams and water spreading systems. What a contrast to the old, slow and costly system of obtaining similar information on foot, horseback and by jeep!

Agricultural Experiment Station forest researchers are also hard at work on finding applications in resource management for satellite imagery.

The forest geneticist or tree improvement research specialist has created his own version of the "green revolution". In practically every State and every Agricultural Experiment Station there are one to a half-dozen research specialists concentrating on the development of improved trees. Their goals are trees that grow faster than their parents, trees with denser wood, trees that are hardier and better able to survive adverse climatic conditions, disease- and insect-resistant trees, and trees that are superior in one or many characteristics.

South's "Third Forest"

The South, the country of the southern pines stretching from eastern Texas to Delaware and from Tennessee to Florida, has seen the greatest application of forest genetics and tree improvement research. This is being accomplished by Agricultural Experiment Station scientists working in close cooperation with similar scientists of the U. S. Forest Service and forest industries.

Seed orchards covering thousands of acres and consisting of the progeny of superior parent trees dot the Southern pineries, long since recovered from such earlier practices as land clearing, poor logging practices, and widespread annual burning to "green-up" the land for grazing.

These seed orchards are the source of an annually increasing quantity of seed for the improved seedlings used in replanting the several million acres cut annually to produce the raw material for lumber, pulpwood, plywood, and dozens of other products. These once badly decimated forests now produce in ever increasing quantities.

The results of more than 25 years of painstaking selection, grafting, breeding, outplanting and other processes utilized by the tree improvement researcher are showing up in terms of shorter rotations, more uniform stands, greater disease resistance, and improved wood quality. The South's "Third Forest" must

produce almost double the present growth by the year 2000 if a timber shortage is to be avoided.

Chestnut and Elm

The American chestnut has disappeared from the hardwood forests stretching from the New England States to Georgia, a victim of the chestnut blight fungus. But some of the genetic material of this once abundant and valuable hardwood is appearing in hybrids between it and various Oriental chestnuts. These hybrids do not have the timber qualities of the American chestnut, at least not yet, but they are blight resistant. Who knows when some persistent and imaginative forest geneticist will come up with a hybrid that combines disease resistance with timber quality?

The American elm's future looks equally dark. The Dutch Elm Disease is slowly but surely killing most of the wild elm in the Eastern United States. It has done the same for the ornamental elms of many cities and towns, and threatens the remainder.

Research with American elm selections, and with hybrids between American elm and Japanese, Chinese, and Siberian elm, may not save the ornamental elms of our cities and towns. But it could provide us in the future with elm planting material that is resistant to the devastating Dutch Elm Disease fungus.

A regional project of the forestry schools and agricultural research stations of the north central region has as its objective the testing of strains of Scotch pines from throughout its range in Europe—from the Arctic Circle of Finland to the mountains of Spain.

Christmas Tree Plantings

Fifteen years after the initiation of these tests the results are being widely applied. Strains with greener color, more hardiness, and greater needle-disease resistance are evident in the numerous Christmas tree plantings throughout the region.

Better Christmas trees is the earliest product of this research, but it will continue to yield results in terms of better Scotch pine ornamentals, and, hopefully, even improved timber producing varieties.

Trees for the prairies have not been overlooked. Siberian elm selections of better form and with stronger crotches are being increasingly planted to break the winds and storms of the vast open country of America's heartland.

Studying effects of air pollution on Scotch pine at Penn State, as part of effort to breed resistant varieties of ornamental and Christmas trees. Fumigation chamber permits repeated exposure of each tree under nursery conditions, using only two needles each time. Pollutants studied are sulfur dioxide and ozone.

Even the cottonwood of the river bottoms of the prairies has felt the tree improver's touch. Strains resistant to leaf rust now are available, thus assuring retention of leaves in late summer and fall, and fuller utilization of the growing season. Complete late-summer and early-fall defoliation by leaf rust was formerly a common phenomenon for cottonwoods planted in shelterbelts and field windbreaks.

Focus on Ecology

Much forestry research at State Agricultural Experiment Stations is focused on ecology—ecology of commercial and non-commercial species, ecology of brush or low-growing woody plants, forest-wildlife relations. Some of the most significant

research accomplishments and contributions have been in this fascinating and complex area of research.

University of California ecologists, for instance, have found that the long-lived Coast redwoods require disturbance of their sites, such as periodic fire, flooding or logging. Otherwise the rich

Top, California scientist studies effect of water pollution on tree growth. Above left, machine developed at Penn State for digging and handling balled plants. Above right, Forest Service scientist uses back pack power unit to drill tap holes in sugar maple, in research project at Northeastern Forestry Experiment Station, Vermont. Note plastic bags on trees for sap collection.

alluvial soil of the stream margins, which grows the largest trees, will be gradually invaded by shade tolerant broad-leaved species that will prevent redwood reproduction or crowd out that becoming established.

This information changes the entire approach to Coast redwood management for park and recreation purposes. Hitherto the most common practice was to protect the area from all disturbance.

Clear Cutting

The present raging debate on the practice of clear-cutting of Douglas fir, lodgepole pine, the Southern pines, jack pine and red pine of the Lake States, and other conifers, is to a major extent a matter of ecological considerations. Most of these species demand full or near full sunlight for reproduction and best growth. Partial cutting of any type results in shading of reproduction, thus reducing rate of growth and vigor.

The greatest present debate revolves around clear-cutting of the northern and eastern hardwoods, a practice that the U. S. Forest Service has recently introduced as a substitute for the previously practiced individual-tree and group selection cutting practices.

This will require an abundance of future research by Agricultural Experiment Stations, forestry schools, and U. S. Forest Service scientists to arrive at compromise solutions to the clear-cutting question.

The role of wildfires and man-made prescribed fires in the management of most of our conifers is being increasingly researched. Prescribed fires are extensively used in the South to reduce brush and hardwood invasion and to prepare planting sites.

Such fire-use is a far cry from the former promiscuous burning of southern forest lands to green them in the spring for early grazing, and for chigger control. As reported by one researcher, "they burned the woods because their pappies burned the woods".

Research has shown that wildfires are generally damaging because few of them burn in the right place at the right time. Prescribed fires used by foresters and ecologists are applied in the right place and right time to produce desired ecological changes.

Disturbance by fire, logging or mechanical means is critical to the reproduction and retention of red pine in Itasca State Park—located at the headwaters of the Mississippi River, for Eastern white pine in Cook State Park of Pennsylvania, for Lodgepole

pine in Yellowstone, for Douglas fir of Olympic National Park, and for many similar nationally famous recreation areas. In fact, it's equally critical for Coast redwoods and the Bigtree of Sequoia and Kings Canyon National Parks.

Agricultural Experiment Station researchers are giving increasing attention to non-timber values of forest lands: wildlife, recreation, water, grazing and esthetics. Development of small- and large-block cutting practices for the common Lake States aspen type, a prime habitat for grouse and white-tailed deer, will help insure the future of these important game species.

Retention and establishment of hardwoods, and even of brush species, in the vast areas of Southern pine plantations is being increasingly recognized as critical to maintenance of good populations of quail and white-tailed deer.

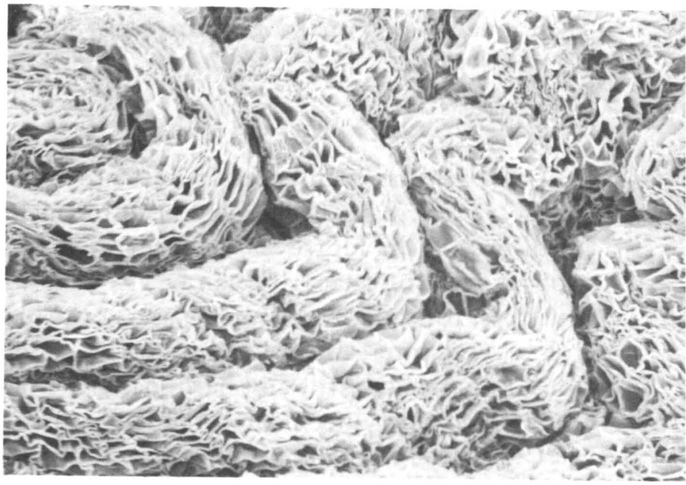
Campground Research

Forested campgrounds are preferred by the rapidly increasing army of tourists and campers seeking relaxation and recreation in forested areas. The selection of such campgrounds, their management to prevent excessive soil compaction, and their periodic rotation are subjects of increasing research. Upon the success of this research rests much of the ability of our forests to withstand future recreational pressure, pressure that is expected to increase manyfold.

Forest lands of the Western, Northern and Eastern States are the source of much of the industrial, irrigation and human-consumption water of those areas. Research is needed on increasing the water yields through modified forest management practices, reducing the effects on water quality by modifying logging practices, and determining the effects on nutrient regimes of logging, fire and various forest management practices.

Where and when, and under what conditions are grazing and timber production, grazing and wildlife production and grazing and water production possible on forest lands? Research must continue to find the answers to these critical questions involved in the millions of acres of forested range lands of the West, forested pastures of the East, and much of the Southern pineries.

How can forest lands produce timber in increasing quantities and still retain their esthetic values for our increasingly urban population? Research on modified clear-cutting practices, shape and size of cut areas, screening from view, and other timber

Left, Washington State animal scientist works with artificial rumen in research on using wood as cattle feed. Right, Oregon researchers made this electron microscope photo of layers of cork cells of Douglas fir bark after treatment with a solvent.

harvest practices is being pursued in an attempt to reduce public concern with the effects of logging on esthetics.

Timber Products

Research to improve wood products, develop new ones, increase the use of low quality timber species, utilize such normally wasted material as bark, and similar forest products research is underway in the half-dozen major and many smaller forest products research laboratories of Agricultural Experiment Stations and associated forestry schools.

Particleboard and related products are being manufactured today to the extent of over 4-billion square feet of 7/8-inch thick board annually. In 1950 the industry was virtually non-existent. These products are made largely from wood wastes or residues and low quality woods combined with synthetic adhesives.

Particleboard has become a substitute for lumber and plywood in many uses. Combined with aluminum, plastics and high density fiber boards it appears in kitchen cabinets, furniture, and dozens of other commonly used products.

Talk about Aladdin and his magic Lamp! Today's forestry researchers are modern-day Aladdins.

Wood-fiber products, from top quality printing papers to hardboards, are the subject of much research aimed at improving

their quality and making them from lower quality woods and recycled wastes.

Finding Uses for Bark

Tree barks normally constitute 10 to 15 percent of the volume of most trees. Bark has largely been burned or placed in landfills to dispose of it. However, concentrated research at a few locations is showing that bark can be effectively used as horticultural mulches, for soil improvement, as a cork substitute, or as a source for several interesting waxes. And it can be incorporated as a filler in particleboards and hardboards.

Sawdust piles once dotted the landscape wherever timber harvest and sawmilling were in progress. No longer is it a waste. It is now used with wood chips for fiber production, as a plastic filler, for fireplace briquettes, and in dozens of other ways, thanks to research. Making better use of logging slash—branches, leaves, stumps and cull materials—is an objective high on the list of utilization researchers.

If good applications can be found for these low-quality wastes and residuals the day of "full-tree utilization" will have arrived.

If You Enjoy Eating, Thank the Machines!

By Kenneth K. Barnes and James H. Anderson

More machines, bigger machines, better machines—they help perform the near-miracle of keeping American agriculture rolling and of putting food on American tables in unequalled abundance. Housewives buy from a plentiful supply of food of incredible variety, high quality, and with built-in work- and time-saving features.

Mechanization of American agriculture has made it possible for less than 5 percent of our people to produce food for all the rest, thus freeing the majority of the population to produce the other necessities and luxuries of life.

Some of the most dramatic changes in mechanization of agriculture have come since 1940. During the depression years of the 1930's there had been a surplus of labor on farms, and there was no great incentive to use labor more efficiently. A farm worker growing corn or barley in 1940 produced for each hour of work only a third more than a worker had produced in 1910.

But in the years beginning with 1940 there was a sharp rise in the output per man in producing many crops. By 1950, a man could produce twice as much grain for an hour of work as he produced in 1940. In 1960, each hour of work produced three times as much as it had in 1950, and six times as much as in 1940.

The 1940's had set the stage for a rapid increase in mechanization. The 1950's were the years of major progress in mechanization of grain and forage crops. The 1960's saw rapid progress in mechanization of cotton and many of the fruit and vegetable crops harvested for processing.

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The 1970's will be the decade of mechanization of the fresh market fruit and vegetable crops, for many of the tasks in production of these crops are still done by hand. When the 20th century comes to a close, food production in America may well have become completely mechanized.

The State Agricultural Experiment Stations play many roles in mechanization. Sometimes it's the obvious one of inventing a new machine. Such was the case in the 1960's when W. F. Buchele, an agricultural engineer at the Iowa Agricultural Experiment Station, invented the giant hay baler. The machine produced a 1,000-pound package of hay in contrast to the usual 75- to 125-pound bale.

The giant bale system provided a completely mechanized means of handling the bale from field to feeding at a lower cost per ton than other baling systems. Farmers were interested. Farm machinery manufacturers recognized this interest and developed their own versions of Buchele's basic system.

This giant bale system is now used on many farms to cut costs and reduce labor in harvesting hay and feeding it to cattle.

There have been many developments in mechanizing the hay harvest. H. D. Bruhn, agricultural engineer at the Wisconsin Agricultural Experiment Station, set out to make handling hay as simple as handling grain. He speculated that if a few handfuls of hay were subjected to high pressure under just the right conditions, the hay might stick together in a small package.

Pancakes of Hay

These packages were originally called wafers, and were thick pancakes of hay an inch thick and six or eight inches in diameter. The wafers could be scooped, dumped, hauled or conveyed much like ears of corn. The Wisconsin work stimulated much interest in State Agricultural Experiment Stations, the U.S. Department of Agriculture (USDA) and the farm equipment industry. The basic concept proved correct, although as experience was gained the details changed.

Today, the commercially produced hay cuber picks up field-cured hay and produces "cubes" an inch and a half square and one to two inches long, at the rate of five tons per hour. This machine is widely used in areas where irrigated hay is grown; research on making hay cubing adaptable to the rain belt continues.

Top right, hay baler that makes 66-inch diameter "round" bales weighing about 1,200 pounds. Top left, Auburn has conducted studies of this type of labor-saving system, with bales stored in a central outdoor area. Above left, hay cuber at work. Above right, hay cubes can be handled and stored like grain.

During the period 1932–39, Agricultural Engineer T. N. Jones and Plant Physiologist L. O. Palmer, with the Mississippi Agricultural Experiment Station, did much work on field curing of hay. They found that in all cases Johnson grass and alfalfa cured substantially faster when the stems were crushed right after mowing. By crushing Johnson grass they found the usual curing time of 72 hours could be reduced to 24 hours.

Hay crushing reduces the weather hazard which is so critical to hay production, and the hay crusher has become a standard tool in haymaking.

Often the Agricultural Experiment Stations develop crop production technology which makes successful mechanization possible. In mechanization of cotton harvesting, Agricultural Experiment Stations helped develop cotton varieties and methods of fertilizing and irrigating which would produce a plant compatible with machine harvest.

Harvesters Get on the Boll

Cotton was one of the last major crops to be almost completely mechanized. A patent was issued for a picker as early as 1850 and in the early 1900's stripper-type harvesters were used, but they harvested green as well as ripe bolls. A harvester which would pick the cotton from ripe bolls and leave the green ones wasn't developed until 1942. After that development, cotton mechanization came in a hurry.

In 1948, about 140 man-hours were required to produce a bale of cotton. Now the requirement is in the neighborhood of 20 man-hours. Most of the reduction in labor demand has resulted from the virtual elimination of hand labor for weeding and harvesting.

Let's look specifically at the application of cotton pickers to irrigated cotton in Arizona. This crop is almost completely mechanized, although the first mechanical cotton picker didn't arrive in Arizona until 1946.

In 1958, some 51 percent of the Arizona cotton crop was machine picked. Machine picking jumped to 62 percent in 1959, 73 percent in 1960, 80 percent in 1961, 92 percent in 1962, and to virtually 100 percent before the 1960's were over.

Many factors have influenced the adoption of mechanization in cotton harvesting, as they have influenced the adoption of mechanization in any crop. Some of these for cotton were: (1) improvement of machines, (2) development and improvement of ginning facilities to handle machine-picked cotton, (3) lack of enough usable hand labor for the work, (4) increased knowledge of the proper application of harvesting machines, (5) development of machines for salvaging ground-loss cotton, and (6) development of varieties and growing practices which resulted in a plant particularly suited to machine harvest.

State Agricultural Experiment Stations were particularly active in development of growing practices which would produce a plant suited to machine harvest.

Uniformity of the cotton crop is critical to efficient machine

harvest. That uniformity depends on getting a full stand of cotton at the first attempt.

The "W-Profile"

In Oklahoma, combined hazards of heavy spring rain and blowing sand often resulted in spotty stands and replanting parts of fields two or three times. So in the early 1950's, engineers of the Oklahoma Agricultural Experiment Station developed the "W-profile" planter to solve the problem.

The new planter placed the seed in a low ridge at the bottom of a deep furrow where it was protected from blowing sand and standing water. Chances of getting a full stand at first planting went up to 80–90 percent. And cotton farmers saved millions of dollars.

Experiment station engineers and scientists have attacked many harvest-mechanization problems. Through the late 1940's, peanut producers used hand labor to harvest peanut plants and place them in stacks to dry. Then the North Carolina Agricultural Experiment Station developed a mechanical system for digging the peanut plant, windrowing for drying, and threshing with a peanut harvester.

The agricultural engineers not only devised an effective mechanical system but also learned how to prevent off-flavors in the peanuts by proper curing during the drying period.

Blueberries and cucumbers are two other crops which North Carolina engineers have done much toward mechanizing. Labor shortages had the blueberry industry headed for extinction until agricultural engineers developed a mechanical blueberry harvester which vibrates the bush, catches the berries as they fall, and conveys them to a wagon.

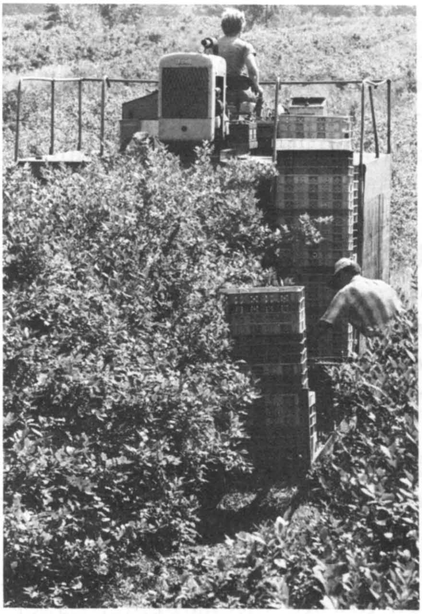
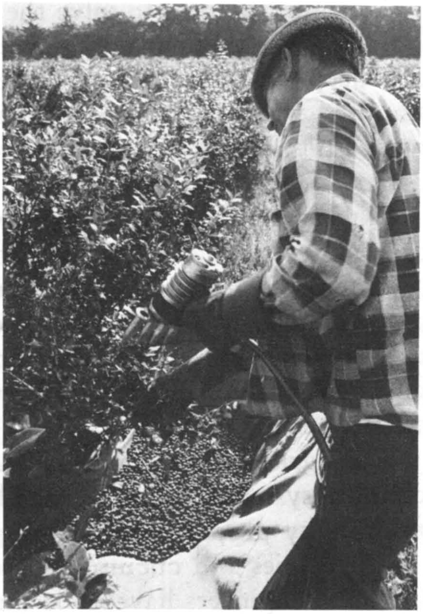
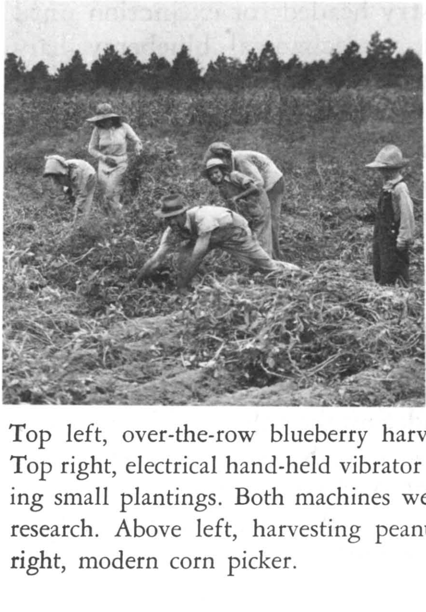
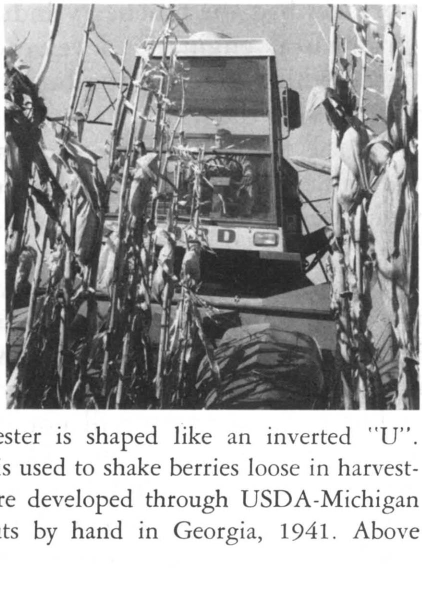
At the frontiers of mechanization in the 1970's are fruit and vegetable crops. Many of these crops are particularly critical in their present requirements for hand labor—labor that is fast becoming unavailable at any price.

This unavailability of labor may result in the loss of some vegetable crops from the market unless they are mechanized. And labor for the producing and harvesting fruit and vegetable crops is lower in productivity than any other labor in the Nation today.

The U.S. economy will not indefinitely tolerate labor at this low level of productivity. The huge U.S. corn crop was once picked entirely by hand, but people had better things to do, and corn harvest is now among the most highly mechanized of harvest operations. This same change will take place in vegetable

and fruit crops, and many of the changes are being made through leadership of the State Agricultural Experiment Stations.

Mechanization of fruit and vegetable harvest is a complex problem. Complex, of course, because of the fragile and perishable nature of the harvested materials. Complex also because vegetable mechanization will not be achieved by mechanical design alone.

Top left, over-the-row blueberry harvester is shaped like an inverted "U". Top right, electrical hand-held vibrator is used to shake berries loose in harvesting small plantings. Both machines were developed through USDA-Michigan research. Above left, harvesting peanuts by hand in Georgia, 1941. Above right, modern corn picker.

Man—a Superior Machine

As a harvest machine, the human body is indeed remarkable. Through its sense of sight and touch, it measures the quality of the product to be harvested. This information is transmitted to the brain, where it is compared with standards stored in the "machine's" memory.

If the fruit or vegetable is ready to be picked, the arm and hand get a signal to grasp the fruit or vegetable, remove it from the plant and put it in a box or sack. The hand and arm are capable of moving through tortuous paths—a different path for each unit of product harvested—and of selecting only the desired unit without taking any trash along with it.

Does the mechanization of vegetable and fruit harvest imply development of machines which will duplicate these sophisticated abilities of the human body? The answer is clearly no. The effective approach is to modify the plant to reduce the degree of selectivity required in harvest and to place the harvested parts in a predictable position in relation to the harvest machine.

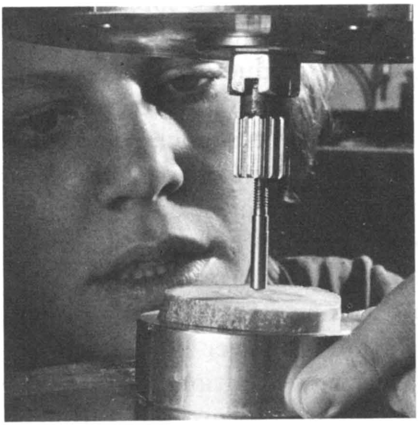
Thus vegetable mechanization is not a problem for the engineer alone. It must be worked out through close collaboration with plant scientists, ultimately with commercial producers of vegetable crop seed, and with vegetable growers.

This was uniquely illustrated in California in the early 1960's when work of the experiment station engineer-horticulturist team, Coby Lorenzen and G. C. Hanna, revolutionized tomato harvesting. A tomato and system of tomato culture for uniform maturity was developed, and a machine which could take advantage of this uniformity was simultaneously perfected. As a result, processing-tomato harvest changed from a hand-labor to a machine job in a few years.

Saving the Pickle Industry

A similar team went to work in North Carolina when labor shortages threatened the pickle industry. Labor for harvesting cucumbers was especially critical. The Agricultural Experiment Station began a joint project with both engineers and horticulturists to develop a mechanical harvester for cucumbers. The plant breeders developed a cucumber plant most adaptable to mechanical harvesting, and the engineers developed a harvester which can go through the field many times without damaging the plants.

Engineers of the Agricultural Experiment Station in South



Top, cucumbers pour from conveyor belt of harvester in Michigan. USDA and Michigan teamed up to develop cukes better suited for mechanical harvesting and handling, and to improve the whole pickle production process. Above left, technician tests slice to determine internal strength of cucumber. Above right, ag engineer and processor check vines.

Carolina began developing a mechanical harvester for fresh market peaches in the 1960's. Working closely with horticulturists, these engineers have developed a machine from which the harvested fruit is entirely acceptable on the fresh market.

The same engineers have applied the experience and knowledge gained from their work with the peach harvester to develop a prototype fresh market tomato harvester. Peaches and tomatoes are highly susceptible to bruising and other damage from machines. But these new machine marvels promise to change the harvesting of two of our most desirable fresh market products from a hand to a machine job.

Agricultural Engineers Bill Harriott and Roger Garrett of the Agricultural Experiment Stations in Arizona and California began working on machine harvest of lettuce in the early 1960's. They worked closely with each other and established basic principles of lettuce harvest mechanization. USDA engineers built upon their work and developed a machine compatible with practices of the lettuce industry.

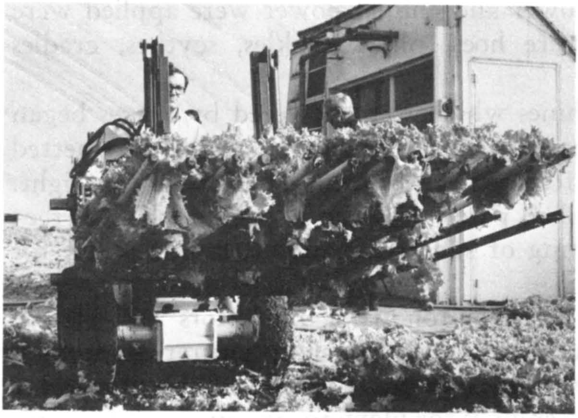
The lettuce industry, with the advice of the State-Federal engineer team, has now taken on development of a commercial prototype.

And Even Strawberries

Much effort is being directed to mechanizing fruit and vegetable crops. Now new machines are being developed for havesting such crops as cantaloupes, oranges and strawberries. Basic principles of mechanization are being worked out by growers, scientists, and engineers wherever these crops are grown.

State and Federal agencies share with agricultural producers, and with the agricultural equipment industry, interest and responsibility for improving the productivity of labor in agriculture. These groups continually share and exchange ideas and information.

As fruit and vegetable mechanization is a major thrust of the 1970's, perhaps mechanization of production of marine animals and plants will be the breakthrough of the 1980's. Even now, Agricultural Experiment Station engineers in such seacoast States



Lettuce harvesters developed by Ohio (left) and Arizona scientists. Ohio machine, tested in commercial greenhouses, may result in more greenhouse lettuce grown in rotation with tomatoes and during winter months.

as Maryland, Massachusetts and Oregon have set their sights on mechanizing the clam, oyster and lobster industries.

Mechanization of agriculture has all come about in little more than 100 years. As the United States prepares to celebrate its 200th birthday in 1976. It's well to remember that an American farmer of 200 years ago would have been perfectly at home with the tools used by farmers in Biblical times. And if we had no tools but those, almost every American would spend most of his working day just producing his own food. Americans would have little time left for exploring space and carrying on the activities which are the backdrop of our life today.

When prehistoric man first began to rely less on gathering his food from untamed nature and began to cultivate plants and keep animals, the energy he used was his own. As he toiled in the field with crude hand tools, he dreamed of ways to do his jobs in the field more rapidly and with less labor. He yearned to control more power than he himself could supply.

He developed tools which could be drawn by animals, and thus became a controller of energy instead of a source of energy for agriculture. That was just the beginning. The desire to control and apply more and more power in food and fiber production continues. Thus, a farm worker who can develop only one-tenth horsepower himself can effortlessly control a 200-horsepower tractor.

Hoe, Hoe, Hoe No Joke

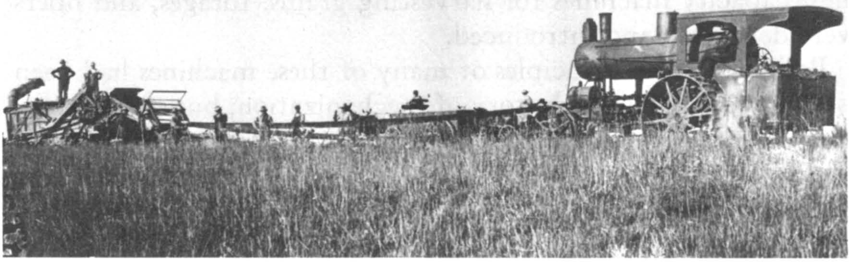
During all time until the middle of the 19th century, tools through which manpower and animal power were applied were very simple. They were hoes, plows, sickles, scythes, cradles and flails.

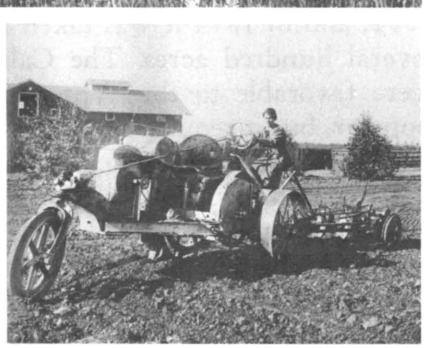
In the 1850's machines which were powered by horses began to be adopted. Development of these machines certainly whetted the farmer's appetite for the heat engine, and the time was right. In 1769, James Watt had patented a steam engine which is recognized as the beginning of successful application of steam for power.

This event opened the door for many innovators to work toward the use of steam power. Thresher manufacturers undertook to make portable steam engines for agriculture. Farmers were also interested in steam engines for plowing, and in the 1850's successful steam-powered tractors were developed.

Application of steam engines to agriculture flourished from 1850 to 1900, but by 1920 the age of steam in agriculture was








Farm machinery through the years. Top left, planting potatoes, and top right, hand cultivators for onions, both scenes in Iowa about 1918. Details are unknown on next lower photo going across page, evidently a steam engine and threshing activities. Pair of photos show thresher, left, and gas tractor, right, in California. Bottom, combines harvesting grain sorghum in Texas, 1968.

about over. Starting in 1890 there was a great deal of activity in developing the internal combustion engine. From 1900 to 1920, great competition arose between steam (external combustion) and internal combustion engines. The internal combustion engine won out to revolutionize American transportation, and it won out to revolutionize American agriculture, too.

From 1920 to World War II the flexible, ever-improving internal combustion engine paved the way for the widespread development and adoption of the basic tools of modern American agriculture. High-speed tillage, planting, and cultivating tools and high-capacity machines for harvesting grains, forages, and fibers were developed and introduced.

Basic operating principles of many of these machines had been established early in the history of mechanization, but the internal combustion engine made effective application of mechanization possible.

40-Horse Combines

For example, a grain combine was developed in Michigan in 1832, and in 1854 it was taken to California where it harvested several hundred acres. The California climate and large fields were favorable to this type of machine. The combine became popular, but it required as many as 40 horses.

Compare the morning job of "starting up" 40 horses on an 1880 combine with the job of starting a 150 horsepower engine on a 1975 combine, and the role of the internal combustion engine in mechanization jumps into vivid relief.

When World War II created a sudden upsurge in demand for farm machinery, all the required elements had been marshaled. Basic principles of many machines had been developed and proved. The internal combusion engine had reached a high level of performance and reliability. The farm equipment industry was firmly established. State and Federal programs of agricultural research and development were on a firm base.

When 1940 brought a sudden need for production of food with less labor, America was ready.

Throughout the mechanization revolution, the State Agricultural Experiment Stations have served as a link between agriculture and the farm equipment industry. Experiment station staffs have included plant scientists, animal scientists, and engineers who have maintained a grass-roots contact with agriculture, developed knowledge fundamental to solving mechanization problems, and worked closely with agriculture and the farm equipment industry in applying this knowledge.

Man-Molded Cereal—Hybrid Corn's Story

By D. D. Harpstead

Thomas Robert Malthus shocked society in 1798 with a rather short essay on population growth and the food supply potential. He predicted that human numbers would increase at a geometric rate over time while the best to be hoped for from food production was an arithmetic increase. Overpopulation, famine and mass starvation were the foreseeable results.

Little did Malthus know that corn, specifically hybrid corn, would delay for almost two centuries the impact of his dire predictions. But Malthus should not be judged harshly. Corn was still generally regarded as an inferior grain three centuries after the voyages of Columbus brought the crop to the attention of the European scientific community.

Corn truly belongs to the Americas. The American tropics gave rise to this food plant long before the dawn of recorded history. Excavations in the caves of arid regions in Mexico yield fragments of diminutive corn cobs which may have been grown and collected for food more than 5,000 years ago.

The history of corn in the Americas is the history of man. Man has changed corn. He has molded it to serve his needs. Corn, as we know it, no longer grows wild. It is a man-dependent crop. It is our attendant servant and one of our greatest benefactors.

Who were the men that molded and shaped the corn we enjoy today? That is our story. Fortunately the modern phases have been recorded, but the first five millenniums will have to remain a dark but impressive mystery into which only a flicker of light can be shed. These glimpses are only brief and widely separated in that time scale.

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Just when man began his systematic selection of corn to produce unique and valuable types is not known. Certainly the priestly leaders of the Central and South American Indian nations were selecting specific types of corn as curios or objects of art. This selection, wittingly or unwittingly, gave rise to thousands of varieties of differing characteristics.

Many of these varieties still exist and are grown in the more isolated regions of corn production. This occurs not only in the Americas but also in Asia and Africa where the varieties were carried by early explorers during the 16th century.

Cotton Mather's Role

Corn may have been ignored by the classical European botanists, but it did come under the recorded observation of several early writers. In 1716 Cotton Mather, better known for his witch hunting activities in the Massachusetts colony, demonstrated that crossing occurred beween two varieties—even when the unlike varieties were grown in separate rows. What Mather put down in writing was the effect of natural hybridization which was to spark the imaginations of inquiring minds up to the present.

No one man can be singled out as the inventor of hybrid corn. All corn as it exists naturally is a hybrid—because it is cross-fertilized. This means that pollen from the male flower, the tassel, is carried by air currents to fertilize the female flower on a different plant, in this case the silk of the ear. Cotton Mather may not have understood what was happening when he made his observations, but others did.

As early as 1812 John Lorain, a gentleman farmer from Philadelphia, purposely crossed varieties of corn to obtain a more vigorous stock. Such activities were fairly common occurrences among the innovative seed producers of that day. However, most corn seed was still produced in fields where no control was placed on the sources of pollen. These varieties became known as "open-pollinated".

Value of the hybrid was recognized for its vigor in growth rate, size, stamina and ultimately in yield. The biological basis for hybrid corn is the phenomenon known as "hybrid vigor".

The story of hybrid corn cannot be told without a brief encounter with the works of Charles Darwin. Darwin was the fresh and free thinker of his day. Among his many books and papers was a discourse on "Cross and Self-Fertilization in the Vegetable Kingdom," appearing in 1876.

Darwin knew of the loss in vigor that occurred when the corn plant was denied the process of cross-fertilization and restricted to self-fertilization. In like manner, he was impressed by the vigor of the plant that resulted when two self-fertilized plants were crossed together. He observed and measured plants but did not measure yield. He concluded that cross-fertilization was generally beneficial and self-fertilization injurious.

Darwin Correspondent

For a more practical minded man, Professor William J. Beal, working with corn was an invitation to serve mankind. Beal studied Darwin's results and corresponded with him about plans for further experimenting with corn.

Let's take a look at Professor Beal, the man. In 1870 he returned from his studies at Harvard to his home State of Michigan to become Professor of Botany at the new and revolutionary Agricultural College of Michigan, now Michigan State University. He taught students in the classroom and he took students to the field. He developed gardens and nurseries and planted experimental forests. He taught botany with a purpose.

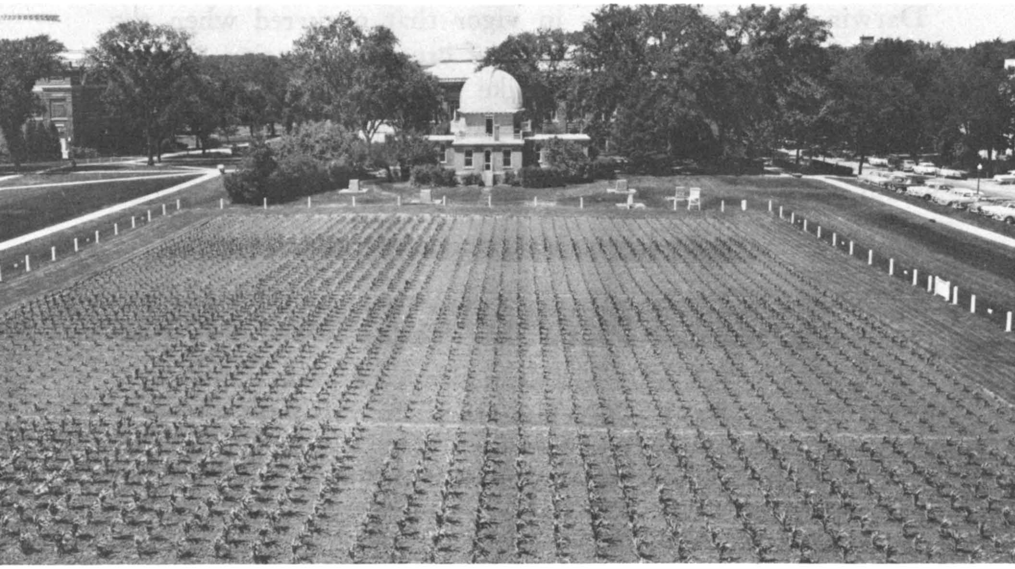
It was only natural that Beal should look for the practical aspects of Darwin's theoretical concepts. Beal chose two varieties of corn, one flint and one dent, to test his ideas on the use of hybrid vigor. These varieties were planted in alternate rows in an isolated field.

When the tassels appeared, all were removed from one variety so that all of the pollen to fall on the silks of the detasseled plants came from the other variety, assuring a true cross. The crossed seed was harvested and planted the following season.

The year was 1877. The hybrid corn was yield tested and increases of 50 percent were reported. Other workers quickly confirmed Beal's spectacular results.

It is difficult to understand why this work did not become an immediate commercial success. We can speculate that the average rugged individualist of his day saw it as belittling to have to buy seed, rather than select his own according to some hypothetical ideal more closely allied to art than to practical production.

Nevertheless, the labors of Professor Beal were not lost. He had invented the most practical way to control the cross fertilization of corn, by simply detasseling the intended female parent—a technique so successful it is still in use today. He also inspired several young men whose names are to appear again and again in



Morrow plots in Illinois, America's oldest experiment field, designated a national landmark by the U. S. Department of the Interior. Plots were established in 1876.

the hybrid corn story. The first of these was Eugene Davenport.

Davenport was named Dean of the College of Agriculture in Illinois in 1895. The focus of hybrid corn development followed him. He appears to have had a genius for recognizing good men, hiring them and inspiring them to productive activities. From this point, the history of hybrid corn becomes an interdependent and interwoven mesh of dedicated men and scientific activities.

"Pedigree" Breeding

Davenport brought to Illinois his former assistant at Michigan State, Perry G. Holden, who had also been a student of Beal. Holden enlisted the aid of Cyril G. Hopkins, a chemist, to investigate the major chemical components of corn and to breed types that would have a superior nutritional value.

Hopkins examined some of the crosses used by Beal and indeed found differences in protein and oil content. He developed a "pedigree" breeding system which led to pure lines; but the "close breeding" was actually a slow form of inbreeding and caused the varieties to lose vigor and result in lower yields.

Hopkins was disappointed and disillusioned. His practical orientation would not allow him to proceed with this work. He did

not realize that he had laid the groundwork for the development of inbred lines of corn.

Inbreeding is the process of matings between close relatives. In corn this can be self-fertilization as well as other forms of close breeding. The net result is inbred lines, and during this process, selections can be made for those plants having the desired qualities.

The work of Hopkins might have ended at this point had it not been for the young chemist he had hired several years earlier, Edward Murray East. It was East who recognized that inbreeding had resulted in depressed yields and sought ways to overcome its effects and still preserve the desired characteristics which had been selected.

The scene now shifts to Connecticut when E. M. East left Illinois to take a position at the Connecticut Experiment Station in 1905. Production of corn in Connecticut was a part of East's responsibilities. He had some of the inbred seed he had worked with at Illinois sent to him, and continued the studies that were to make his name prominent in the annals of hybrid corn.

The Two Giants

While East was initiating his work in Connecticut, George Harrison Shull also began inbreeding corn only 100 miles away at Cold Spring Harbor, Long Island, New York. He, like East, observed that inbreeding reduced yield and vigor and served to isolate individual lines of corn that differed greatly. With continued inbreeding, unique characteristics were "fixed" in the plants and became identifiable for the individual lines. This work led Shull to describe his program as a "pure-line method" of corn breeding.

The work of both East and Shull proceeded along parallel lines, neither aware of the activities of the other. Each made crosses between inbred lines. Each observed that selected combinations of crosses could give yields superior to the best varieties of the region when the crossed seed was planted the following season.

Shull is generally given credit for the first public announcement in 1908 of work which can be directly traced to the principle leading to modern hybrid corn. Very similar results obtained by East were quick to follow. It was inevitable that competition would develop between these two giants, and perhaps the generations of scientists who followed have spent more

time choosing up sides than either of them did. We know that each held the other in deep respect and that scientific exchanges between them were frequent.

Shull had approached his corn breeding from a highly theoretical position, but saw in his results what he thought would be an immediate practical application for agriculture of his day.

East had developed the applied orientation in his initial work. He concluded that even superior crosses made from two weak inbred lines of low productivity would not be practical for the farmer because of the difficulty of growing the seed and the resulting high seed costs.

Although some of Shull's inbreds were used for seed production, history proved East correct and the discovery of practical hybrid seed production had to wait for yet another development. Fortunately this development was not long in coming.

Shull moved to Princeton and away from applied corn breeding in 1912. East moved to Harvard in 1910 and his work at the Connecticut Experiment Station was continued by Herbert K. Hayes.

"Double Cross" Pays Off

While at Harvard, East came in contact with a young science teacher, Donald F. Jones, who became his student. When Hayes left Connecticut for Minnesota, Jones succeeded him and fell heir to the Connecticut corn work. It was Jones who cracked the barrier that had held up commercial application of hybrid corn. In only three years he had recognized the advantages of the "double cross". (Fortunately for mankind it was not the double cross of villainous connotation.)

It was well known by 1914 that by crossing together two unrelated inbred lines a vigorous, highly productive crossed product would result. This became known as the "single cross". Jones merely carried this one step further and crossed together two unrelated single crosses. This was the double cross. Its success was immediate. Seed could be harvested from the highly vigorous and productive single-cross female parent.

Jones did not make the first double cross but clearly demonstrated and publicized its value. Many men caught the vision and a new era for agriculture was ushered onto center stage.

The casual reader may imagine incorrectly that the work with corn inbreds and their crosses was the only corn improvement work in progress. Actually, corn variety improvement was the

art of the day. The time, energy and money spent on this effort was far greater than that being spent on the embryonic hybrid corn investigation.

The commercial "open-pollinated" corn varieties of the early 1900's were largely of the "dent" type. A dent corn was one in which the crest of the kernel collapsed upon maturity, leaving the surrounding edges of the kernel higher with a "dent" in the center.

This type of corn appears to trace its ancestry to intermingling of the soft, floury, gourdseed corns of the Southern United States with the hard, New England flint corns. These were the two strains of corn that Lorain worked with in Pennsylvania in 1812. Many crosses, some planned, others chance events, occurred between these types, giving rise to the dent corns which were widely distributed long before hybrids came on the scene.

Improved corn varieties, however, were not a matter of chance. Men who were skilled observers selected specific types of corn to become the seed of future crops. Unfortunately many of these selections were based on artistic appeal with little or no relationship to productivity.

Start of the "Corn Belt"

No one man was more typical of the age of variety selection than P. G. Holden; the same Holden who earlier had been a student of Beal and was a coworker with Hopkins, East's original employer. He became the leading evangelist of corn through the first two decades of the 20th century. He spread the known science for corn production in Illinois, Iowa and finally to most of the States that now comprise the "Corn Belt".

Holden preached variety selection. He selected for the showy qualities of the corn ears and made his audience aware that not all ears were the same, but that each ear had its individual characteristics.

The result was that many locally adapted open-pollinated varieties were created which matched environmental needs of a particular area. Unfortunately, all these many efforts did not accomplish one of the chief aims—to materially improve the yield of the variety. No doubt this was a great disappointment to Holden and many others when it became a demonstrated fact in the early 1900's.

The failure of variety selection to produce increased yields suddenly became unimportant. Jones in 1919 had opened the door

to practical hybrid corn seed production with his use of the double cross. Men like Henry A. Wallace caught the vision of Jones' significant discoveries and laid the groundwork for the great seed corn industries of the United States and the world. Hybrid corn was destined to become the base for all corn production. The open pollinated variety could not compete.

The double cross was the spark needed to shift into high gear the already active corn breeding programs at many of the State experiment stations. Cooperative programs were developed with the U. S. Department of Agriculture (USDA). Hayes in Minnesota, Jenkins in Iowa, Brink in Wisconsin are just a few of the men who served to carry the whole new research philosophy to a waiting agriculture.

This burst of new activity generated a great search for sources of inbred lines that would yield hybrids adapted to a region and be superior in yield to the local varieties. A superior Connecticut hybrid would not necessarily be superior when in a foreign environment. The local open-pollinated varieties of corn became the ready sources of these inbred lines.

More than 20 years were to pass between discovery of the double cross and the significant adoption of hybrid seed. These were not wasted years. Our Land Grant Universities, through their Cooperative Extension Services, educated whole generations of farmers to the value of hybrid corn. Thousands of applied demonstrations were conducted and advantages of the new seed were preached. In a like manner, research efforts were expanded in the Agricultural Experiment Stations and a whole new phase of plant breeding evolved.

Hybrid Vigor Phenomenon

Donald F. Jones made a second significant contribution to the world of science almost at the same time he was developing the double cross. He clearly perceived and demonstrated that the phenomenon of hybrid vigor could be explained on the basis of Mendelian inheritance. This second contribution of Jones generated a body of scientific work which leaves many questions unanswered even today.

Understanding the hybrid vigor phenomenon, predicting the results of crosses, and directing the selection of superior inbreds have given rise to a great increase in scholarship in genetics and plant breeding. Individual accomplishments are far too many

to cite in detail. Only a few outstanding contributions can be outlined here.

F. D. Richey of USDA was the first to concentrate desired and favorable characteristics into selected inbred lines rather than depending upon a chance segregation of these characteristics during the inbreeding process. Others looked for new secrets of inheritance and genetic functions that operated outside of the Mendelian laws to explain the vigor of the hybrid combinations. Whole new inbred line selection schemes were developed.

Each new scheme was designed to take advantage of the theoretical causes of the hybrid phenomenon. Perhaps these reached their peak in the works of Fred H. Hull of the Florida Agricultural Experiment Station.

New giants grew in the corn fields. These were men who understood both theoretical genetics and applied plant breeding. George F. Sprague and his students at Iowa are outstanding examples of the new generation of scholars who contributed to both practical and academic arenas.

This new generation produced new inbred lines, new hybrid combinations, and little by little built the greatest body of genetic knowledge of a single crop the world has ever known. All of that took place mainly in the 30-year period between 1920 and 1950.

This work has taught us that when more is known more questions can be asked.

High Speed Computers

In searching for more answers H. F. Robinson, R. E. Comstock, and P. H. Harvey and their colleagues at North Carolina described genetic functioning in terms of mathematical models, and linked plant breeding problems to the high speed computers. Their publications, starting in 1949, provided new tools for the science.

One group of scientists discovered that a certain selection of corn could be isolated that would not produce functional male flower parts. The female flower, the ear, developed normally. These plants were called "male sterile".

It was soon learned that this factor was in the cell cytoplasm and could be transmitted by the maternal parent. It could be transferred to certain inbred lines and these lines used to produce seed when crossed with normal types without the laborious task of removing the tassels from each female plant by hand.

The crowning accomplishment in this series of discoveries

came when a way was found to restore male fertility to genetic systems previously male sterile. Credit for the discovery is generally given to the incomparable Donald F. Jones and Paul C. Mangelsdorf.

It's amazing to realize that in corn such vital functions of life as reproduction could be turned on and off almost at will. To American agriculture and to world food production it provided new levels of economy and efficiency. Hybrid seed became more abundant and relatively cheaper.

Race Horse Performance

The discovery of male sterility made it practical to produce commercial seed of the single-cross hybrid. This idea had been abandoned in the early years because of seed cost. These single crosses performed like carefully bred race horses. They exhibited qualities for specific situations and added great precision to our corn production systems.

The same benefactor, male sterility, almost spelled disaster for the American corn crop in 1970. A new form of an old disease, Southern Corn Leaf Blight, spread rapidly through the Corn Belt that year. Plants were hypersensitive to this disease when they also carried the factors for male sterility.

Disaster was averted by the fast action of the Agricultural Experiment Stations, USDA, and the private seed companies. In

Georgia's champion corn grower for 1973 and 1974. Opposite page, New York farmer checks stage of maturity of corn he grows to feed dairy cows.

one year's time they reconverted hybrid seed production to the normal male fertile types.

The final chapter can't yet be written in the saga of hybrid corn. It is easy to see the impact to date. In the early 1930's average U. S. corn yields were 22 bushels per acre. By 1940, when hybrid seed occupied 40 percent of the corn acreage, yields had jumped to 35 bushels per acre. Today, virtually all of our corn is produced from hybrid seed and our average yields approximate 95 bushels per acre. In 1973, a Michigan farmer actually produced 306 bushels per acre for a world record yield.

Total corn production in the United States in 1973 was enough to provide each of our citizens with 1,500 pounds of grain for his individual use. But very little of our corn production is actually consumed directly. It is fed to livestock and we in turn consume the animal products.

We Grow Half of World's Corn

This supply of corn is one half of the total world production, and the miracle is renewed each year. Little wonder that corn has become the envy of the world. All of this has taken place in the incredibly short period of less than 100 years with the end not in sight.

New hybrids are being bred that produce two and even three ears per plant. The vast untapped resources of the genetic stocks

of corn from Central and South America are yet to be used in our commercial types. Plant breeders are just beginning to re-appreciate the corn variety selection work of the early 1900's and to rebuild new bases for further progress in corn improvement.

Man has always molded corn. The ancients could make only gradual changes in a few easily modified characteristics. Today, our tools are much more powerful. We can make corn sweeter, change its color, plant height, maturity and growth habit. We can breed types with starch that can be made into plastics. We can modify its nutritional quality and its kernel characteristics. Literally dozens of new areas of science have grown up around the corn crop.

Modern science has made corn our "genie in a lamp". It still remains for us to be intelligent enough to ask the right questions of our most willing slave.

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Golden Beans From China Now Our No. 1 Cash Crop

BY ROBERT W. HOWELL

The Soybean! The "Golden bean" . . . !

Now one of America's most important crops, the soybean was not the subject of the pilgrim's pride, nor a gift of the American Indian, nor a product of colonial trade.

The soybean's early history is recorded on the other side of the world. In China, it predated the Christian era by more than a thousand years. It was and is a staple of Oriental diets, and the raw material of countless village industries.

But in the last few decades the soybean has become a major element of world commerce. By 1973, soybeans had become our No. 1 cash crop, the leading export commodity, the major alternative crop of midwestern and southern farmers, the world's most effective producer of protein per acre, and the hope of starving millions for a better diet.

How was this miracle achieved? It was made possible by a combination of fortuitous conditions . . . a need for oil and protein, accentuated by war-time demands and post-war population growth . . . land newly available as production of other crops outpaced demand, partly because there were fewer draft animals and thus less need for land for feed grain production . . . the ability of soybeans to adapt to a wide range of climates and to farming methods already known to corn and cotton farmers . . . and removal of legal restrictions on margarine.

But there was another element, just as important or even more so. First a few and then many more men and women of vision, imagination, energy, dedication—remarkable people and institutions who saw the potential of the soybean and worked hard to make that potential a reality.

Robert W. Howell is Head, Department of Agronomy, University of Illinois. He was formerly leader of soybean investigations in the Crops Research Division of the Agricultural Research Service, USDA.

First mentioned by Mease in 1804 in Pennsylvania, the soybean (*Glycine max* (L.) Merr.) increased in importance slowly. Few varieties were available by the turn of the century, perhaps no more than eight in 1898. Early varieties selected in experiment station programs included Haberlandt from North Carolina; Dunfield, Mandell, and Richland from Indiana (Purdue); Scioto from Ohio, Illini and Chief from Illinois, Mukden from Iowa, and Arksoy from Arkansas.

C. A. Mooers of Tennessee noted in 1908 that the flowering habit of soybeans was influenced by the date of planting. His observation led to the discovery, 10 years later, by W. W. Garner and H. A. Allard of the U. S. Department of Agriculture (USDA) that the length of the day controls the initiation of flowering. This phenomenon is called "photoperiodism" and is now known to affect flowering in many plants and reproductive behavior of some birds.

Soybean research in USDA in the early part of the 20th century was the responsibility of C. V. Piper. But the man who deserves the most credit for establishing soybeans as a significant crop in the United States was W. J. Morse. Morse began his work with USDA in 1907 and soon was responsible for soybean research. For more than 40 years, until he retired in 1949, he was the guiding light and inspiration of soybean researchers in USDA and the States alike.

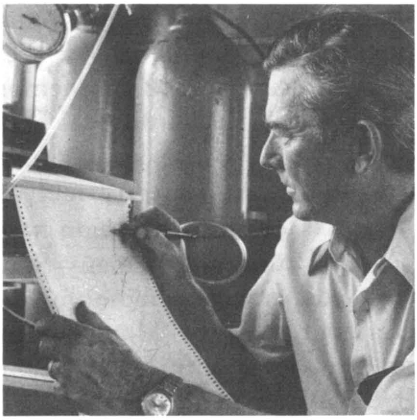
He cooperated with all who responded to his invitation, and promoted soybean production by direct face-to-face contact with farmers. Morse was one of the founders of the American Soybean Association and was its president three times. He published more than 75 articles about the soybean, and in 1923 was co-author with Piper of a book *The Soybean*.

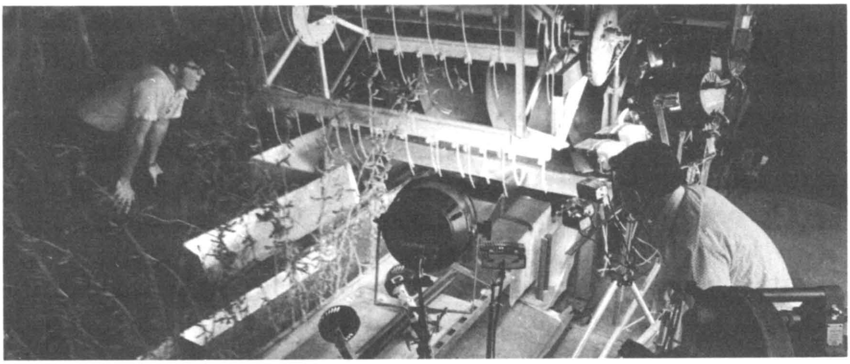
Travels in Manchuria

Morse made a plant exploration trip to Manchuria, Korea and China with P. H. Dorsett from 1929 to 1931. Most of the soybean varieties now in use in the United States are descended from lines which he collected on that trip or which Dorsett had collected on an earlier trip.

The potential of the soybean was recognized by many people of great vision in the State Agricultural Experiment Stations in the early decades of this century. Nearly every State had a "Mr. Soybean", some more than one, and the titles were well deserved.

These experiment station and USDA leaders were joined by in-





Top, Illinois and USDA scientists confer as mobile machines capture soybean plot air samples that are then pumped by hose to trailer in background. Center right, checking recordings in trailer of carbon dioxide concentrations and sunlight intensity, to determine basic life processes of plants in field. Center left, culturing soybean tissues in solutions containing radioactive compounds, at an Urbana lab. This permits studies of how the plant produces protein and oil. Above, high speed movie camera records feeding of soybean stalks into a harvester reel and experimental cutterbar.

dustry leaders of comparable vision. Firms such as A. E. Staley Co., which in 1921 offered a soybean contract to farmers with a guaranteed price of $1.35 per bushel, encouraged farmers to grow soybeans and offered them a market.

Official coordination of the soybean programs in experiment stations and USDA began in 1936. In that year the U.S. Regional Soybean Industrial Products Laboratory was established at the University of Illinois in Urbana under authority of the Bankhead-Jones Act. Utilization research was transferred to the Northern Regional Research Laboratory in Peoria, Ill., in 1942.

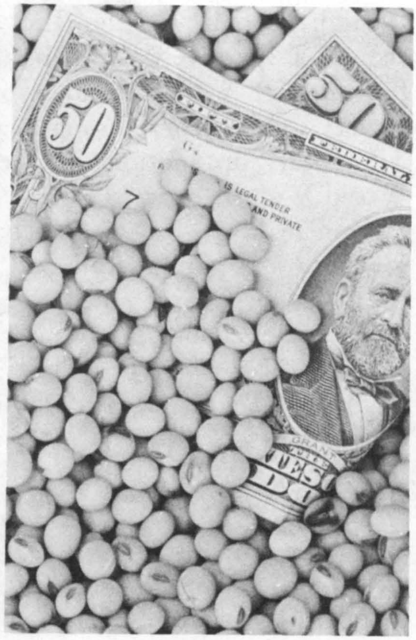
Production research, mainly plant breeding and production practices, remained at Urbana as the U.S. Regional Soybean Laboratory. A cooperative effort of State Agricultural Experiment Stations and USDA, the program of the Soybean Laboratory is still defined in Memoranda of Understanding between USDA and the stations of the North Central and the Southern States. USDA has located most of its soybean production research staff at State Agricultural Experiment Stations.

Little or no distinction was made between a "Federal" and "State" program in many States. Much of the credit for fixing this cooperative philosophy in soybean research is due to O. S. Aamodt, who was Morse's immediate superior and had been head of the Agronomy Department at Wisconsin before joining the USDA staff in 1939.

Aamodt was dedicated to the importance of cooperative USDA-State effort. He counseled new Federal employees at great length to this effect. Cooperation became the tradition, the norm, in soybean research and has continued so.

The most significant expansion of soybean production research in both numbers and scope occurred under the leadership of Herbert W. Johnson, who was leader of soybean investigations from 1953 to 1964, and is now head of Agronomy and Plant Genetics, University of Minnesota. He emphasized the importance of basic research and interdisciplinary studies, and the need to relate research to practical problems. Following Aamodt's counsel, he stressed the importance of State-Federal cooperation.

The first soybean variety to come from the cooperative USDA-State program was Lincoln, released in 1943. Actually the hybridization from which Lincoln was selected was done by C. M. Woodworth of Illinois several years before the Soybean Laboratory was established. Later came Hawkeye, Ogden, Roanoke, Clark, Lee, Amsoy, Corsoy, Beeson, Calland, Cutler, Wayne,



Left, geneticist Richard L. Bernard examines a vine-like ancestor of modern soybeans. Right, soybeans are an important cash crop.

Pickett, Jackson, Hardee, Williams, and many others. Previous varieties had been the result of selection from introductions, not hybridization to combine the good points of two parents.

The variety development program is based on a strong foundation of genetic fundamentals. Soybean breeder-geneticists have, therefore, been able to make major contributions to genetic theory.

An example is the study of the genetic controls of maturity by R. L. Bernard, with USDA at Illinois. Maturity of a variety is governed by numerous genes and is influenced by environmental conditions. Using a "back-crossing" technique to produce closely related genotypes which differed by a single morphological trait such as leaf shape, Bernard discovered that a single gene can condition a difference of as much as 23 days in time to flowering and 18 days to maturity.

Most breeding effort has been on so-called industrial varieties as contrasted with "vegetable" types. But C. R. Weber, with USDA at Iowa State, developed Kanrich and Kim, and later the large-seeded Disoy, Magna, and Prize, varieties intended for vegetable use, as contrasted with crushing for oil and protein.

High protein varieties, Provar and Protana, were released in the 60's respectively by Weber and A. H. Probst, with USDA at Purdue. H. W. Crittenden of Delaware developed Verde, a variety suitable for canning as a green bean.

Soybean production in the South increased rapidly after World War II. E. E. Hartwig, with USDA at the Delta Branch Station in Mississippi, is widely recognized for his leadership of southern soybean research, and for varieties and production concepts which he introduced.

The original breeding and genetics programs were gradually supplemented with programs in plant pathology, plant physiology, weed control, nematology, agricultural engineering, and entomology.

Phytophthora Rot

The first major threat to the soybean crop was phytophthora rot. First observed in northwest Ohio and northeast Indiana in 1948, the cause was identified as a species of *Phytophthora* by A. J. Suhovecky and A. F. Schmitthenner of Ohio in 1955. It was soon found to occur widely in soybean-producing areas of the North Central States and the Delta.

A simple genetic type of resistance, found in Blackhawk

Testing moisture percentage of soybeans from test plots and weighing them, at University of Maryland, Eastern Shore. Goal is to breed soybean varieties resistant to corn earworm.

variety by Bernard and M. J. Kaufmann of Illinois, provided the means of breeding varieties that are resistant to phytophthora rot.

Discovery of the soybean cyst nematode, *Heterodera glycines* Ichinohe, near Wilmington, N. C., in 1954 by N. N. Winstead, and the discovery within a few years of the nematode in soybean fields in the Mississippi Delta, posed another serious threat to soybean production.

A major effort to find genetic resistance was initiated with a program to screen the entire germplasm collection.

Unlike the simple genetic mechanism of resistance to *Phytophthora,* resistance to the nematode was very complex. It was eventually shown to involve at least five genes, one very closely linked to the gene causing the undesirable black seed coat.

When a source of genetic resistance was found by J. P. Ross and C. A. Brim, with USDA at North Carolina, an intensive program to breed resistant varieties was started.

After a yellow-seeded resistant line was discovered, Pickett variety was introduced in 1965. Custer and Dyer were released a short time later. These varieties provided protection against the nematode. Race 4, discovered in 1969 in Arkansas, caused severe injury to the newly developed resistant varieties. Resistance to Race 4 has been found and is being used in the development of varieties which will be resistant to it.

China Variety Saved Day

Pickett, Custer, and Dyer derive their resistance to the cyst nematode from the variety Peking, which was introduced from China in 1906 and named "Peking" in 1910.

Peking was of little significance in the growth of the soybean industry until the cyst nematode attack occurred. This is an outstanding example of the importance of preserving germplasm, for without the resistance available in Peking the cyst nematode might have had a devastating effect upon soybean production.

Many other soybean disease, nematode, and insect problems are known and are receiving research attention. So far, soybeans have escaped such ravages as the southern corn leaf blight of 1970 or the rust epidemics that constantly threaten wheat.

Living Together

The soybean is a legume and as such is capable of using nitrogen from the air through a symbiotic relationship with a bacterium,

Rhizobium japonicum (Kirchner) Buchanan, which infects the roots and forms nodules.

Specific affinity relationships exist between bacterial and soybean genotypes, but, so far it has not been possible to replace established *Rhizobium* populations in the field with other strains that may be better suited to current varieties.

Chemical control of weeds in soybean fields is probably the most important technical advance in soybean production during the last 10 years. Chemicals that were popular and effective in corn, such as 2,4-D and atrazine, are toxic to soybeans and, therefore, could not be used. But selective herbicides for soybeans began to appear beginning in the late 40's.

Dinoseb, chlorpropham, and naptalam were among the earliest soybean herbicides. They have been replaced now with highly selective and effective chemicals such as amiben, trifluralin, and 2,4-DB.

C. G. McWhorter, with USDA at Mississippi, has made notable contributions to soybean weed control in the Delta, including innovations such as herbicide-impregnated wax bars and directed sprays which made it possible to apply herbicide to weeds without exposing the soybeans. His double rate of trifluralin application is widely and effectively used to control rhizome johnson grass. By the early 70's, nearly all soybean growers were using chemicals for weed control.

Modern soybean farming is an example of mechanized agriculture. Early interest in mechanization was shown by a demonstration of a combine for harvesting soybeans at the Delta Branch Experiment Station, Stoneville, Mississippi, in 1926. But losses in harvesting have continued to cost soybean growers some of their production. Harvest losses can reach several bushels per acre.

Important technological advances in processing and use of soybeans have provided expanded markets. Introduction of the solvent extraction process—replacing the expeller—produced a higher quality oil and meal.

Deodorizers Developed

Techniques were developed to deodorize the oil, making it more acceptable for salad and cooking oils, which now comprise the largest use of soybean oil.

Removal of restrictions on colored margarine in the years after World War II and consumer acceptance resulting from experi-

Availability and uses of soybean oil, year beginning Oct. 1, 1973[1]

Availability	**Million lbs.**
Beginning stocks	516
Production	8,999
Total Available	9,515
Use	
Domestic Use	7,300
Exports	1,425
Total Use	8,725
Domestic Uses	
Food:	
Salad & Cooking Oils	3,070
Shortening	2,185
Margarine	1,514
Other food products	12
Total Food Uses	6,781
Non-food Uses	492

Food use as percentage of total domestic use: 92.7

[1]Source: Fats and Oils Situation, FOS—275, November 1974, USDA—ERS.

ence with margarine during the war led to expanded use of margarine.

In 1974 more than 90 percent of the domestic use of soybean oil was margarine and other edible products (see first table). The principal non-food products of soybean oil are paint and varnish, and resins, each comprising about one percent of domestic use.

Improvements in feeding of broilers with high protein meal were followed by similar developments in feeding laying chickens and swine, and in use of soybean products in pet foods and in beef cattle concentrates. About three-fourths of the soybean meal is used domestically, mostly in commercial feeds (see second table). Soy flours, which may be defatted or full-fat, are used as additives in bread and cake flours. Soybean meal is used in industrial products such as adhesives, in emulsion paints, and in stabilizers.

Many companies—as well as USDA's Northern Regional Research Laboratory at Peoria, Ill., and Agricultural Experiment Stations—contributed to these advances.

Traditional use of soybeans in the Orient was for human food. Nor were food uses overlooked by early workers in the United

Availability and uses of soybean meal, 1973–74[1]

Availability	**Thousand tons**
Stocks—Oct. 1, 1973	183
Produced	19,674
Total Available	19,857
Use	
Domestic	13,817
Exports	5,533
Total Use	19,350
Stocks—Oct. 1, 1974	507

[1]Source: Soybean Digest Bluebook, 1975.

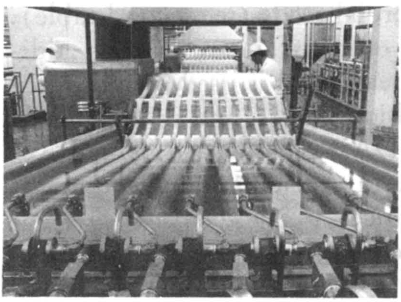
States. Sybil Woodruff and Olive Zwerman of Illinois published numerous recipes for use of soybeans and soybean products. Use of soybean oil was promoted in the preparation of potato chips and desserts, as well as use of green soybeans for canning and as fresh vegetables.

Research of the Peoria group was also concerned with use of soybeans in oriental foods, important for the Japanese market, and in simple processing methods suitable for use in villages of less-developed countries.

More recently, food scientists have developed soybean products for use directly in human foods. Texturized vegetable protein, already in commercial use as a meat extender, is a good example.

In 1961 the Minnesota legislature authorized several soybean research positions. This was the first State action specifically directed toward building a soybean research program.

During the last few years the American Soybean Association has taken the initiative leading to adoption of programs to provide funds from growers for soybean market development and



Liquid protein fed into a spinning machine emerges as bands of tiny white fibers, in this vegetable protein foods plant in Iowa. After color and flavor are added to the bands, they will be cut into various shapes and sizes, packaged and sold.

research. There are now many soybean positions in the experiment stations.

Meanwhile the staff of USDA has increased more slowly because of policies limiting the number of Federal employees.

A significant private (commercial) soybean breeding effort began during the 1960's. Stuart and Hampton varieties were developed at Coker Pedigree Seed Co. in South Carolina. In 1964 a group of seed producers organized Soybean Research Foundation, Inc. to conduct a breeding program based at Mason City, Ill. In 1967 a soybean breeding program was initiated by Peterson Seed Co. of Waterloo, Iowa, now a division of Pioneer Seed Co.

Enactment of the Plant Variety Protection Act in 1970 has stimulated more companies to begin breeding soybean varieties.

Beans and the World Scene

Soybean researchers in the northern States have cooperated for many years with colleagues in Canada. Southern researchers have cooperated with colleagues in Mexico, Brazil, Guyana, and other parts of Latin America. The U.S. Agency for International Development (USAID) encouraged soybean tests in India and elsewhere.

An International Soybean Resource Base, INTSOY, was established at the University of Illinois under USAID sponsorship in 1973. The INTSOY program concerns development of soybeans for food uses in the less-developed countries, and training people from those countries to carry out soybean research and extension programs in their home countries.

The soybean industry has encouraged soybean research with industry funds and by supporting appropriations for soybeans. The National Soybean Processors Association provided grants to universities through the National Soybean Crop Improvement Council beginning in 1949. The American Soybean Association Research Foundation was established in 1965.

Communication among officials who are responsible for allocating funds from these various sources is encouraged by the National Soybean Research Coordinating Committee, which has members from Federal agencies, State Experiment Stations and extension services, industry associations, and State soybean promotion boards.

The soybean has come of age in American agriculture. It has a

golden future, too, because of its great potential in providing calories and protein for diets around the world.

An increase in U.S. soybean yields of one bushel per acre produces additional protein equivalent to the total needs of nearly 23 million people. Is it any wonder that nutritionists and humanitarians join American farmers in crying for higher soybean yields!

Problems remain—a need to increase per acre yields, a need to adapt to tropical environments, a need to conteract antinutritional constitutents, and a need to adjust to constantly changing markets. These challenges are but opportunities to the soybean research community that now has the size, vigor, and skills to deal successfully with tomorrow's problems, and is as dedicated as those who went before.

For Further Reading:

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A Million Gallons of Water For a Single Acre of Food

BY WYNNE THORNE

Among the elements needed to sustain plant life, water is unique in the tremendous quantities required. In our arid West one acre of irrigated crop land will commonly receive a million gallons or more of water a season.

No wonder the farmer has been obsessed with water! He has sought through magic, religious rites, and more recently through cloud seeding, to increase precipitation. Where such activities have proved inadequate, billions of dollars have been spent to store, transport, and apply water to arid soils.

In the arid and semi-arid lands that occupy more than half of the earth's surface, man has devised ways to conserve moisture under rain-fed situations, and he has devised ways to use water efficiently by irrigation.

Irrigation is not a recent device. Remains of imposing structures for irrigation along the Nile, Indus, Ganges, and Hwang Ho rivers bear mute evidence to the ingenuity of man before recorded history. In the United States similar evidence near the Salt River in Arizona indicates a flourishing large scale irrigation system 2,000 years ago.

Conditions surrounding these ancient irrigation structures reveal struggles with many of the same problems we have today: silt-filled canals, waterlogging of soils, over-irrigation, and salt accumulation. Drainage either was not understood or seldom practiced.

Early Catholic fathers from southern Europe who established missions in the Southwest introduced the first irrigation practices to this continent in modern times. A dramatic advance in irrigation began in 1847 when the Mormon pioneers diverted City

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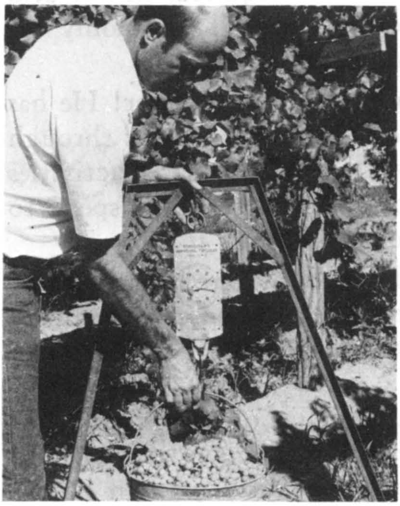
Creek to water sagebrush-covered land so it could be farmed in what is now the center of Salt Lake City.

Stories of the success of the Mormons in developing a productive agriculture in an otherwise arid and forbidding environment soon spread to almost all parts of the West. The expansion of irrigation agriculture was often a secondary product of the influx of people attracted by gold, silver, and other hopes for sudden wealth who, disappointed in finding immediate riches, remained to farm.

The expansion of irrigation in the West has been substantial and continuous. Irrigated acreage in the 17 Western States more than doubled in the 30 years between 1939 and 1969 to attain a total of over 36 million acres.



Left, weighing wine grapes from experimental plot at Washington State irrigated research center. Goal of studies is to develop a new industry in State. Below, irrigated Texas corn field.

Since 77 percent of the land irrigated in 1969 was developed with private investment, irrigation has been an attractive investment opportunity. In fact, of 14.5 million acres newly irrigated since 1950 only 23 percent was under Federal projects, or the same proportion as that developed before 1950.

Investments in these facilities are expensive, but abundant, assured yields and diverse opportunities for farm management practices make expansion of irrigation attractive. No other system of farming holds such opportunity for applying science to farming, nor offers such security against the perennial threat of drought.

Water scarcities in farming are not limited to the arid West. Almost every farming region suffers periods of drought, and with high value crops such as tobacco, vegetables, and fruits, financial losses from even temporary droughts can be high. Irrigation agriculture has thus spread widely; the 1969 U.S. Census of agriculture reported substantial irrigated areas in every State except Alaska.

Although only slightly over 10 percent of the Nation's cropped land is irrigated, this land includes 58 percent of all orchards, 56 percent of our potatoes, and 50 percent of vegetables.

During the early irrigation development period, most irrigation was initiated by individuals or small groups diverting water from rivers or streams through short canals to irrigate nearby land.

Soon the possibilities for such simple diversions were exhausted and larger schemes were instituted, first, on a modest scale by private development companies and later by public effort through the Federal Government. Several State governments also have become important sponsors.

Recently, the larger irrigation development projects have been made multipurpose, combining such functions as generation of electric power, flood control, and recreation.

The Giant Hoover Dam

A notable example of an initial multipurpose regional approach to irrigation was the development of Hoover Dam as an important phase of the Colorado River Basin Project.

Rapid development of agriculture in southern California and Arizona in the early 1900's created needs for additional water, electric power, and control of floods that repeatedly wasted water to the Salton Sea.

Such problems could be met only through construction of large-scale water control facilities on the Colorado River. This required agreement among the seven states that claimed rights in the river's waters. Such an agreement was reached in the Colorado River Compact of 1922.

In 1928, after extensive deliberation, the Boulder Canyon Project Act was passed by the U.S. Congress. The Act provided for construction of Hoover Dam and associated hydroelectric installations, and for construction of the All-American Canal to carry water to the Coachella and Imperial Valleys in California.

When completed, this was the first major multipurpose river system project. Others that followed include the Columbia River Basin Project, the numerous reservoirs and related facilities in the Upper Colorado River Basin, and the many units of the California Water Plan.

Under early conditions of simple diversions from streams and rivers, water was cheap and plentiful. With no dependable evidence available on the water-holding capacity of soils, many farmers reasoned that if a little irrigation was good, more should be better. Even though the soil in the root zone of annual crops could seldom hold more than six inches of water, individual applications of several times this quantity were often made with the mistaken belief that the water was being stored for later use.

Dreaded White on the Ridges

And so the errors of the ancient irrigation-based agriculture were repeated. Soils became waterlogged, particularly those in the lower elevations. With water accumulation came white incrustations of salts on the ridges, and the term "alkali" became one of dread among irrigation farmers.

With rapid increases in population in the West coming at the same time as a rapid expansion in irrigated land, competition for limited supplies of water has been intensified. This has led to extensive investigations of measures that might increase the water supply.

Most water in streams and lakes of the arid West originates in mountain zones having higher precipitation. In Utah and Nevada over 90 percent of the water available for irrigation originates at elevations above 7,000 feet. Water leaving mountain watershed areas includes rain and snow minus what is lost through evapotranspiration from soils and plants.

Studies in California and Arizona show that under suitable

Sheep graze on irrigated farm in Washington's Columbia River Basin Irrigation Project area.

conditions, replacing deep rooted and heavy water absorbing tree and shrub vegetation with shallower rooted grasses and forbes (broadleaved herbs) will increase the yield from watersheds.

One method of controlling types of watershed vegetation is through controlled grazing. Sheep and some wildlife species prefer shrubs and trees, while cattle usually prefer grasses and forbes. Times and intensities of grazing also affect survival of different plant species.

However, public interest in environment and esthetics, and concern over man's manipulation of natural conditions, have opposed broad scale changes in vegetation. Further, a large proportion of the effective watersheds are publicly owned and much is covered by forests. So, while changes in vegetation could increase available water supplies, little has been done to achieve this goal.

Cloud Seeding

Increasing precipitation is a promising potential. Careful measurements of changes in precipitation have demonstrated that during favorable storm conditions the quantity of precipitation may be increased as much as 20 percent by seeding clouds with silver iodide.

Some seeding can be done conveniently from a mountain by passing silver iodide into a hot flame that vaporizes the salt and expels it upwards into the clouds. In other instances aircraft have been used.

Unfortunately, cloud seeding is successful only with moisture-laden clouds having restricted temperature characteristics. In many western areas, however, precipitation comes largely as snow that accumulates during winter months in mountain watersheds and provides stream flows and irrigation water in spring and summer.

In such situations seeding of winter storm clouds has been relatively successful. And since the normal snow pack provides for such water losses as evaporation and use by native vegetation, an actual rise in stream flow from a 10 percent increase in snow pack may exceed 15 percent.

Many canals lose as much as 10 to 30 percent of their water in a mile. Lining such canals prevents seepage and helps reduce waterlogging and salt accumulation in soils. Thin plastic films are currently the most popular, but special soil cementing agents and asphalt preparations are used too.

Control of weeds in reservoirs and canals, and in areas adjacent to stream beds, also can save large quantities of water. Water-consuming weeds near stream beds have been estimated to use over 15 million acre feet of water annually in the West. Its removal is costly, however, and wildlife interests and others have opposed eradication of such shrub and tree habitats.

Efforts to control evaporation losses from streams and reservoirs have had only small success. Studies have centered on covering reservoirs with thin films of chemicals such as hexadecanol. Unfortunately wind and other disturbances have caused breaks in the film so that benefits have been limited to quiet water bodies of usually less than two acres.

Water Quality

One major factor in water supply has been the quality of the water. Irrigation decreases water quality by leaching salts from soils and concentrating them in the water returning to the stream. Urban and industrial users commonly add organic and mineral materials to water.

Establishment of water quality standards at state boundaries of interstate streams is causing a re-examination of water use which contributes to these conditions.

Although most quality standards have not been fully established nor rigidly enforced so far, water use practices in different river systems are under intensive study. Available information indicates that the inevitable imposition of water quality standards

California scientist takes water sample as part of State-wide survey.

will have major impacts on all water users, and especially on irrigated agriculture since it has become the major consumer of water.

Some irrigated areas have good natural drainage so that excess water can move downward and laterally through the soil. In other instances, especially in the extensively irrigated areas, the movement of excess water is impeded by impermeable subsoil conditions. In such areas water accumulates in the soil, salts are concentrated, and eventually crop growth is injured.

As a solution, drains are being installed and maintained in today's irrigated farms.

Drainage research has concentrated on the design and perform-

Out West, water rights are one of the prime determinants of land value.

ance of different types of drains. Permeability tests of soil and subsoil materials provide good indices for calculating the depth and spacings of drainage laterals, but drainage in some clay soils of low permeability remains a problem.

Water Vs. Wine and Women

A common saying in the arid West is that more men have lost their lives in fights over irrigation water than over wine or women. And so, much attention has focused on rights to use water. The rights to water are usually based on the Doctrine of Appropriation which includes seniority of use.

Commonly, the first developers of irrigated farms on a stream have claimed and often used more water than was necessary for good farming. To control such abuses, appropriation rights have been limited to quantities that can be verified as beneficial.

The situation is further complicated by the fact that laws may be quite different when applied to developing underground water as contrasted to diverting water from streams.

The legal question as to who owns and controls water is be-

coming increasingly complex. In extensive watershed systems, water wasted or excessively applied on one farm becomes the primary source of water for farms farther down stream. The question of ownership of water that could be saved by lining canals and efficient irrigation practices is too often a hindrance to the adoption of needed conservation practices.

Little agricultural research in the West preceded the Hatch Act of 1887 which provided for establishment of State Agricultural Experiment Stations. A notable exception was the appointment of E. W. Hilgard as Professor of Agriculture at the University of California, Berkeley, in 1874. Almost immediately he became concerned with "alkali" soils, and drew apt analogies between conditions near Stockton and those in India.

Hilgard understood the consequences of excessive application of irrigation water, the need for drainage, and the different types of "alkali" and methods of treatment. By the early 1890's effective treatments were devised that were closely similar to those used today.

Engineers and early experiment station scientists in California and Colorado were among the first to be concerned with the "duty of water," expressed as the number of acres that can be irrigated with one continuously flowing stream of one cubic foot per second. Data were collected by measuring size of stream and length of use by different farmers or groups of farmers in relation to the area of land being irrigated.

These early measurements gave such varying data as 50 to 300 acres being irrigated by a stream of one cubic foot per second of water. But for intensive irrigation periods, values as low as 10 acres were reported.

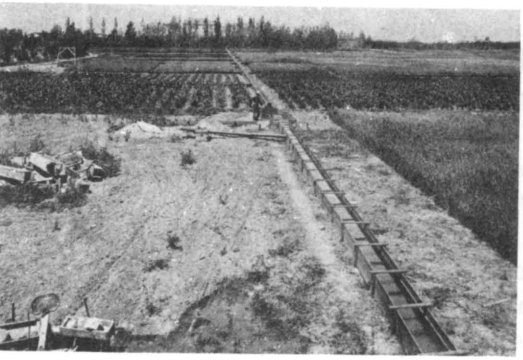
Court Orders

A continuing concern has been to devise water conserving practices to maximize the area served by a given stream of water.

In many areas with water shortages, the quantity of irrigation water that may be used per season per acre is limited by court order. Depending on climate and length of growing season this commonly falls in the range of three to four feet depth of irrigation water per acre of cropped land.

With newer practices employing scientific designs even lower quantities can support high crop yields.

The first irrigation experimental plots were apparently established by J. W. Sanborn at the college experimental farm at




Left, one of earliest irrigation field plot experiments, Utah, about 1893. Right, irrigating potatoes with siphons in Utah, 1958.

Logan, Utah, in the summer of 1890. Among the variables studied were: night versus day irrigation, flooding versus furrow methods of application, differences in time between irrigations, and relations between irrigation practices and fertilizing with farm manure.

Studies in Utah were followed a year or two later by similar studies at Fort Collins, Colorado; Laramie, Wyoming; California, and Arizona. While early investigations concentrated on methods of irrigation, frequency of watering, and quantities to apply, the emphasis gradually shifted toward efficiency of water use and maximizing yields per unit of water and other inputs.

Improved water application efficiencies were attained by leveling land, using shorter runs between head ditches, and using catchment basins at the bottom of fields and pumping this water back to the head ditches. (A head ditch is an irrigation ditch across an upper slope from which water is drawn into furrows.)

Further steps toward reducing labor requirements in irrigation and precise timing of water applications have been attained by solid set and center pivot sprinkler installations instead of movable types, particularly for high value perennial crops. More recently trickle irrigation systems are being used for further economies in labor and water use. This system of wetting a limited part of the soil by applying water from a series of controlled drip-joints in plastic tubes reduces evaporation losses and supports good crop yields.

Irrigation also can circumvent temperature problems. Where warm waters have been available from springs or industry, their use in irrigation has brought about earlier warming of soils and germination of seeds.

"Ditch rider" in Nevada works a headgate to start irrigation water on its way to crops. Headgates measure amount of water used, besides controlling the flow.

Frost Losses Cut

Sprinkling has had limited success in reducing frost damage in early spring or fall. A successful venture has been the recent experiment in Utah to reduce fruit losses from frost. Sprinklers turned on at regular intervals when air temperatures rose as high as 45° to 50° F. The cooling effect of moisture evaporation delayed the opening of fruit trees blossoms by more than two weeks, sufficient to reduce damage from spring frost.

A much debated issue has been the availability to plants of water stored in the soil.

Early workers concluded soil moisture was readily available to plants anywhere between the soil's full moisture capacity and the point at which plants wilt.

With technological developments plus subsequent detailed experiments, evidence became conclusive that plants are retarded in growth as water becomes increasingly scarce in the soil root zone. The trend has been strongly toward more frequent irrigations well before signs of wilting occur.

Salt was also found to exert a detrimental effect by increasing the force which plants must exert to absorb water.

Evapotranspiration losses from a growing crop increase only modestly as crop yields advance. Carefully timed irrigations, with calculated quantities of water to keep soil moisture near ideal for crop growth, will use less water than the older irrigation practices.

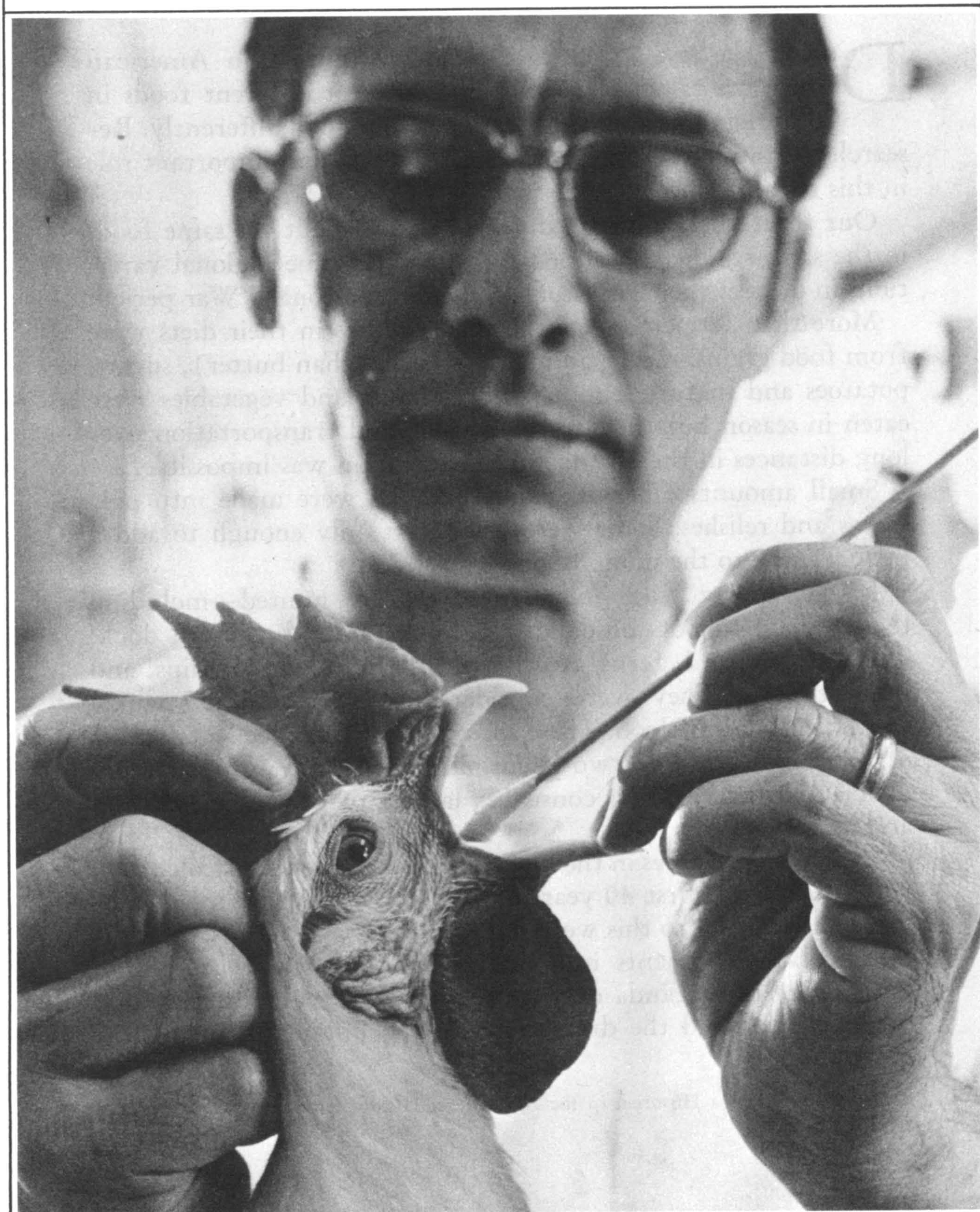
Providing a favorable soil moisture situation by irrigation, adequate fertilizers for a favorable nutrient status, and improved crop varieties to bring rapid growth and high yields, have established the basis for scientific farming at a level never known before. The limited rainfall in most western irrigated areas make possible optimum yields and optimum quality because of farm practices possible with irrigation.

In the West there are thousands of small, inefficient irrigation companies. Although studies have pointed convincingly to the potential economies in water conveyance costs and water conservation by combining many of these companies, seldom have there been any substantial changes.

Social science studies have evaluated the membership in these companies and shown among other things that the older and less educated the water users are, the more reluctant they are to change. Such studies also suggest that improvement of information programs may lead to more effective reorganization and restructuring of water distribution systems.

Although irrigated agriculture is facing increasing competition for water and even though there are additional problems needing solutions, evidence indicates an increasingly important role for irrigation in assuring a reliable and high quality supply of food.

TOWARD A BETTER LIFE



Home Food Preparation Undergoes Big Changes

By Jane M. Porter

During the last 75 years a major revolution in American diets has taken place. We not only eat different foods in different amounts but we prepare our food differently. Research in State Experiment Stations has played an important role in this revolution.

Our forefathers a hundred years ago ate about the same foods in the same seasonal rotations and with the same regional variations in diets as their ancestors of the Revolutionary War period.

More than 80 percent of the food calories in their diets were from food grains, meats, animal fats (other than butter), sugars, potatoes and mature legumes. Fresh fruits and vegetables were eaten in season but they are perishable, and transportation over long distances in the absence of refrigeration was impossible.

Small amounts of fruits and vegetables were made into preserves and relishes. Some were dried, but only enough to add a little variety to the monotonous winter diet.

In the spring wild greens were eagerly hunted—including tender young shoots of dandelion, polk, lamb's-quarters, dock, mustard, pigweed, ferns, Russian thistle, meadow cowslips, and snow thistles. They were considered a "spring-tonic" which would cleanse the blood. These spring greens are excellent sources of vitamins A and C, two essential nutrients that were notably deficient in winter diets consisting largely of cereals, meats, and animal fats.

Significant changes in the kinds of foods in the family diet took place during the first 40 years of the 20th century. Among factors contributing to this were shifts in relative food prices, technological developments in food transportation and processing, nationwide propaganda during World War I for wheatless and meatless days, and the dramatic and well publicized discoveries of vitamins.

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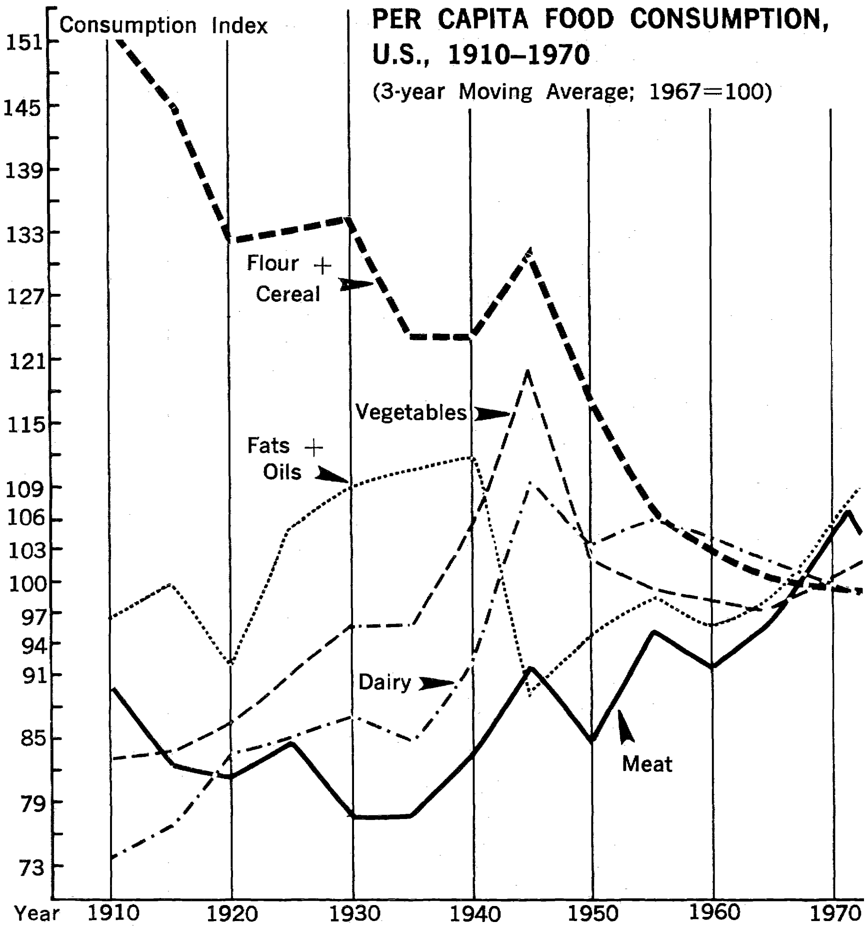
During the depression of the 1930's, many families produced most of their own food.

The State Agricultural Experiment Stations were important contributors to the new technologies and to research on vitamins. Indirectly they had contributed to the changes in the relative prices of foods through research which made dry-land farming and irrigated farming profitable, through improved varieties and means of combating insects and diseases, and through contributions to food technology.

The area in crops expanded relative to the area in pastures and grasslands. At the same time population was increasing rapidly. Food prices increased, particularly during World War I, but increases were larger in meat prices than in other food prices.

Production and consumption of dairy products and eggs was increasing, due to experiment station research in animal breeding, nutrition and disease, and handling and processing of dairy products.

The depression years of the 1930's reinforced the trend in dietary changes. Both rural and urban families faced with loss of cash income tried to meet part of their food needs from home food production. The results of experiment station research on fruits and vegetables, backyard poultry flocks, and rabbits for meat were widely available in popular bulletins, through Extension services, and formed the basis of regular feature articles in newspapers and magazines.



Source: USDA, Food Consumption Prices, Expenditures, ERS Supp. For 1972 to AER No. 138
All Figures Totals Except Dairy Which Excludes Butter

World War II brought rationing of sugar, fats, meats and canned fruits and vegetables, further directing consumption away from these products and towards eggs, milk products, and fresh fruits and vegetables. By this time the term "protective foods" was popularly applied to these latter foods.

Nutritionists had worked out dietary standards for families at various income levels. These were simplified by organization into seven basic food groups which were used in mounting an intensive nutrition education program.

Laboratory scientists had learned to synthesize some vitamins during the 1930's. As a wartime measure, refined cereal grains were enriched with three B vitamins, iron, and calcium. Oleomargarine was fortified with vitamin A, and milk was fortified with vitamin D.

Food rationing during World War II did not restrict total food consumption or decrease the nutritional quality of family diets. In fact, with increased income due to full employment and overtime work, Americans were eating better than they ever had before.

The Problem With Potatoes

Forty years ago the housewife was completely in the dark in purchasing potatoes. Sometimes the potatoes would mash well and turn out white and fluffy. Sometimes they would be heavy and soggy. In boiling, potatoes often developed brown streaks or sloughed off their outer layers. There were no satisfactory chemical or physical standards for judging the cooking quality of potatoes. Neither the variety nor the raw appearance of the potato gave any clue.

Investigators in the State Experiment Stations in Maine, Vermont, New York, Colorado and Montana during the 1930's resolved many of these problems.

It was found that sugar content of the potato was a primary factor governing its cooking quality. Potatoes stored at temperatures near freezing retained a high sugar content. When cooked the sugar tended to caramelize, causing browning and sogginess. Several days storage at room temperature would convert the sugar to starch. The remedy: Don't keep potatoes in the refrigerator for several days before cooking.

Mineral impurities in cooking water were frequent causes of discoloration.

Research discoveries that some vitamins were water soluble, others were fat soluble, and still others easily destroyed by heat led to suspicions that unnecessary nutrient losses were taking place in food after it reached the family's kitchen.

Research on meat cookery began in 1929 at the Missouri Experiment Station. By 1936, six stations—Iowa, Kansas, Minnesota, Missouri, Texas and North Dakota—had organized a committee on meat cookery. Their studies concluded that low temperature roasting of meat resulted in less shrinkage, less loss of nutrients, and improved tenderness.

Meat drippings were found to be high in nutrients and their use in soups, sauces, gravies, and stews was recommended.

Open pan roasting provided the attractive outer browning formerly gained by searing at high temperatures. Use of a meat thermometer was strongly recommended. This resulted in public demand for meat thermometers and open roasting pans.

A quiet revolution in meat cookery took place as the new methods were disseminated through extension agents, stove manufacturers, public utilities, magazines, and cookbooks.

The meat cookery project was soon followed by research on cooking of other foods. This was a landmark in experiment station research because it was organized as a national cooperative project on the conservation of nutritive values of foods. It was first announced in 1941.

Within three years 46 stations in 45 states were cooperating, along with the U. S. Department of Agriculture (USDA) Bureau of Human Nutrition and Home Economics, and the USDA vegetable breeding laboratory at Charleston, S.C. In each State Experiment Station, several departments were cooperating with the home economics department.

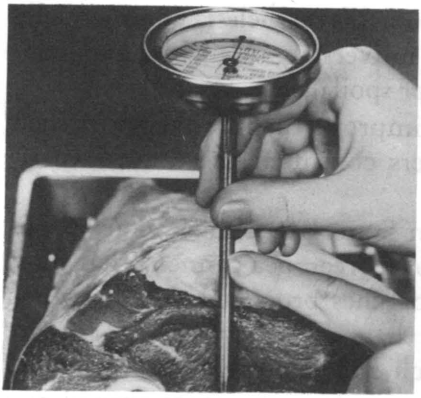
Research soon demonstrated that there was a large loss of vitamins in fruits and vegetables between harvesting and consumption. The amount of the loss could be greatly reduced by certain methods of handling and preparation.

Immediate and continued refrigeration from harvesting to cooking reduced losses. Quick cooking in minimum amounts of water helped to conserve vitamins. The cooking water had a high vitamin content and should be eaten with the vegetables or used in soups, sauces or gravies. Today most people cook vegetables in tightly covered saucepans, with only enough water to prevent burning.

A large volume of basic and applied research was carried out under the umbrella of the National Cooperative Project on the Conservation of Nutritive Values in foods. Corn in the form of cornmeal, grits and hominy supply most of the calories of family diets in some parts of the country but processing methods denuded them of much of the vitamins, mineral and protein content of whole grain corn.

Experiment station workers in South Carolina developed a method of incorporating vitamins and minerals in gelatinized ground grits, and reducing this product to particles the size and color of commercial products. These were then mixed with the regular commercial product as carriers of the enrichment.

Nutrition educators tried unsuccessfully to teach people to eat unpolished brown rice because it contained vitamins, minerals and proteins not present in the more highly processed white rice. The discovery that the B vitamins dissolved in the cooking water of vegetables would be gradually reabsorbed into the vegetable



Left, good cooks began to use meat thermometers when research demonstrated that low temperature cooking of meat reduces shrinkage and produces more flavorful roasts. Right, American food variety and abundance at every season is envy of most of world.

tissues afforded basic knowledge for developing processes to conserve the nutrients or enrich white rice. The processes have been adopted commercially, with resultant products marketed as "enriched" rice.

George III and the Tin Can

Preservation of food from one season to the next has always meant the difference between a full stomach and an empty one. The American colonists knew how to preserve food by drying, salting, pickling, fermenting and smoking, skills known since the dawn of recorded history. Then in 1810 two inventions revolutionized food processing: (1) Nicholas Appert in France invented the process of sterilizing foods in airtight containers, and (2) a patent for manufacturing a tin can was granted by George III in England. Ten years later canning plants were operating in the United States.

Appert's method of processing cans or bottles submerged in boiling water was quite satisfactory for fruits and acid vegetables like tomatoes. But there was a high rate of spoilage in corn, green beans, green peas and similar vegetables, meat and fish canned by this method. Invention of the pressure cooker by A. K. Shriver of Baltimore in 1874 enabled canners to process foods at temperatures up to 250° F instead of 212° F, the boiling point of water. It greatly reduced losses due to spoilage and was in general use by canneries within 20 years.

The number of canning establishments increased from less

than 100 in 1870 to 1,800 in 1900. Nevertheless, commercially canned food was expensive, not universally available, and continued to have a bad reputation for spoilage.

In seeking to reduce losses and improve the reputation of their product, some commercial canners consulted the State Experiment Stations in the mid-1890's.

H. L. Russell of the Wisconsin State Experiment Station observed on examining the records of a green pea cannery that most of the spoilage had occurred in batches processed on days when the processing time had been less than normal. He was fortunate in working with a cannery which had kept records. Many did not at that period, and some unscrupulous operators opened and reprocessed spoiled cans.

The problem of the canners was that long processing resulted in a product which was not very attractive or appetizing, so they tried to minimize processing time. Russell was able to reduce spoilage from 5.0 percent to 0.05 percent by increasing pressure from 10 to 15 pounds and increasing processing time from 26 to 28 minutes.

Concurrent work by the New York State station at Geneva produced similar results, and USDA's Office of Experiment Stations disseminated the new knowledge to the general public in Farmers' Bulletin 73 of 1898.

This information was helpful to the canning industry, but was of no value to the homemaker. She had no pressure cooker and had probably never heard of such a thing. She made preserves and pickles and canned a few peaches, cherries and tomatoes, but did not attempt to can lima beans, string beans, corn, peas, or asparagus.

The homemaker used whatever jars, bottles and stoneware were available and could be sealed by corks or paraffin or a combination of the two. She used the open-kettle method because paraffin would not remain in place during a boiling water bath process.

More affluent homemakers canned in Mason jars, invented in 1858. These were sealed by a rubber gasket and a screw top or by a spring clamp and glass lid with a rubber gasket. However, all glass was still hand blown and relatively expensive.

Mechanization of glass blowing in 1903 made possible the mass production of glass food containers, greatly reducing the cost of Mason jars. Home canning of non-acid vegetables using the Appert method soon became widespread.

Meanwhile, chemists and bacteriologists in the State Experi-

ment Stations and elsewhere were learning more about yeasts, molds and bacteria. It was found that most of these in the growth stage were readily destroyed at 212° F, but that in the dormant stage (spores) they were much more resistant to heat.

In 1906 an innovative researcher at the Oregon State Experiment Station applied this knowledge and devised a system for intermittent processing. With this system, processing at lower temperatures would kill the active organisms and an interval would allow the activation of spores, which would then be killed by a second processing period. A third period was added on a third day to ensure a complete kill.

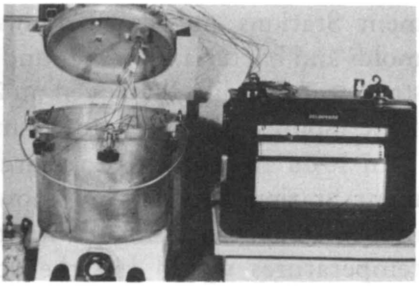
The advantage of this process was that it prevented overcooking, preserving the product's texture and appearance. This method, together with the single stage water-bath process, was the standard one recommended by Federal and State extension services through World War I. However, by 1917 a small portable pressure cooker-canner of riveted steel or aluminum was on the market and this was recommended for meat and fish.

The water-bath processing methods were so effective in eliminating spoilage that people became less cautious in using canned goods. However, there was one bacteria, *Clostridium botulinum*, widely distributed in soils and harmless in the presence of oxygen, which, if it developed in the absence of air, produced a deadly toxin. If it was the only surviving bacteria in otherwise sterile canned goods there were no warning signs of spoilage. It was very resistant to heat, surviving several minutes at even 240° F.

During the period from 1916 to 1924, numerous cases of botulism poisoning occurred in the United States and Europe. This triggered extensive research on the problem by public health services and public and private experiment stations on both sides of the Atlantic.

Although there were no formally organized regional, national or international projects on botulism, researchers from California to Scotland and Germany were working on various aspects of the subject. Channels of communication through professional societies and government agencies such as USDA's Office of Experiment Stations were functioning so effectively that researchers were quickly informed of new knowledge. Within a few years following the isolation of *Clostridium botulinum*, researchers in State Agricultural Experiment Stations from Massachusetts to California had found its spores in samples of their soils.

When USDA research workers devised a technology for re-

Right, thermocouples inside canning jars are checked to insure cooking temperature high enough so botulism bacilli are destroyed. This also determines necessary processing time for home canning of various types of food. Left, canning tomatoes in improvised boiling water bath. Photos were taken in 1940's.

cording the temperatures inside cans during processing, research workers in State Experiment Stations quickly applied it to processing in glass jars.

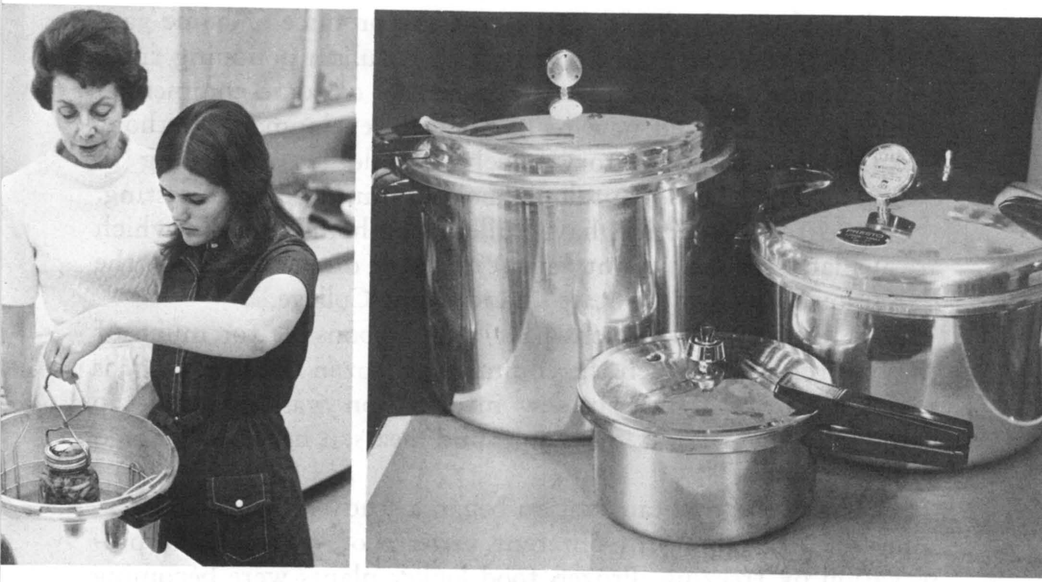
USDA began recommending pressure processing for non-acid or low-acid vegetables to homemakers in the early 1920's. However, water-bath processes continued to be widely used until after World War II. Thousands of housewives had successfully canned by this method all of their lives.

The botulin toxin occurred infrequently, under conditions where it went undetected until the food was eaten and caused illness and death. Cases went unrecognized or unreported so that the public was not especially alarmed. Still, many homemakers routinely boiled all canned vegetables before serving. Perhaps the people who continued to can during the inter-war years were thoroughly experienced and attentive to sanitation in the preparation and canning of vegetables.

These circumstances changed abruptly during World War II. Thousands of women who had never canned began to can foods from "Victory Gardens" or from the market place to supplement their quota of rationed canned goods. Few owned or had access to canning pressure cookers.

Many agencies, public and private, were giving out conflicting canning instructions. Although all State colleges recommended the pressure cooker as the first choice method for canning non-acid or low-acid vegetables, some still approved other methods. The cases of botulism poisoning that occurred during World War II were all traced to home canned food.

In 1943 USDA issued a warning against tasting food before boiling if it was non-acid and had been canned without a pres-



Right, not all pots that cook with pressure are suited for canning foods. Two pots in rear may be used for canning because they have gages that control pressure accurately. Pressure saucepan in foreground with 15-pound pressure control is designed for quick cooking and should not be used to can. Left, Louisiana nutritionist watches young homemaker demonstrate using a pressure canner to preserve green beans.

sure cooker, or canned in one which had not been tested for accuracy of pressure. A study of pressure gages by the Nebraska State Experiment Station in 1938 had revealed that only 36 percent of the canners tested had gages accurate with ± 0.5 pound.

Concurrently, intensive research was undertaken by the Massachusetts State Experiment Station to determine exact processing times necessary for all types of foods in various sizes of glass containers, types of closures, and sizes and types of pressure canners. A little later USDA began research in this field.

By 1948, new procedures and timetables had been developed using all the testing devices previously employed in developing procedures for commercial canning. The more precise procedures made it possible to reduce processing time. The result was that the appearance, taste and nutritive values of home-canned foods were improved.

Boil 20 Minutes and Live

However, home-canning is a precise science and variations from recommended procedures, which might occur where in-

experienced canners begin to preserve the produce of home gardens, could result in a new outbreak of botulism poisoning from home-canned food. The recent experiences of some commercial canners, who adopted new technological developments without making adequate laboratory checks, should be a warning to everyone. The rule is, if in doubt boil 20 minutes before tasting.

State extension services have bulletins on home canning which are available through county agent offices or directly through the Extension Service of the State's Land Grant College.

State Experiment Stations have been responsible for much of the research upon which the commercial frozen food industry is based. To the extent that new information was applicable to home freezing of fruits, vegetables and meats, it has been adapted and disseminated.

The Washington State station began a study in 1936 to determine the adaptability of different varieties of vegetables to preservation by freezing. Frozen food locker plants were becoming common in rural areas, and by 1940 a number of stations were publishing bulletins on the preparation and packaging of foods for frozen storage. At the same time the experiment stations began pointing out the need for satisfactory home storage for both home processed and commercial frozen foods.

Refrigerators with across-the-top freezer compartments were on the market before World War II stopped the production of durable consumer goods. When production was resumed, virtually all makes featured this improvement.

Although Americans enjoy the greatest abundance and most variety in foods of any people in recorded history, significant numbers of us still do not have diets which meet the National Research Council's "Recommended Dietary Allowances" for nutrients.

Some of us suffer from hidden hunger. We do not eat enough foods containing vitamins A, C, some B vitamins, calcium and iron. Good sources of these nutrients are green leafy vegetables, dark yellow vegetables, citrus, tomatoes, whole grain cereals, milk products, eggs, meats and legumes.

Our diets tend to be too high in fats and sugars. Such diets can be contributing factors to obesity, heart and circulatory diseases, and diabetes.

Numerous bulletins on food and nutrition, food preparation and storage, and family food budgeting are available from county home demonstration agents, State Experiment Stations, and USDA. Most are free for the asking.

Lots of Better Things For Home Sweet Home

By Jane M. Porter

Why do most of the pots and pans made in the United States have flat bottoms and straight sides? Because in the 1930's researchers in the State Experiment Stations of Maine and Washington carried on thermal tests with cooking utensils and found that such pans with tight-fitting lids made the most efficient use of heat in cooking.

They also found that the ideal material, if it could be engineered, would be a metal with high conduction for the bottom and a metal that was noncorrosive for the sides and interior. Industry did the rest by fusing copper and stainless steel.

Little research in home economics was carried on in the State Experiment Stations before 1925. Any such research was labeled Agricultural Engineering or Nutrition. The Illinois Station, for example, completed a five-year study of septic tanks in 1926. West Virginia published a bulletin on Farm Water Supply and Sewage Disposal Systems the same year, and New Jersey was engaged in extensive work in farm sewage disposal at the same time.

These studies established scientific data on the functioning of septic tanks and the most effective sizes and shapes. They provided the basis for formulating standards so that industry could mass produce components, and health departments could set standards.

The Purnell Act of 1925 authorizing additional Federal funds for research in State Agricultural Experiment Stations specifically mentioned home economics research as one of the fields to be pursued. The year before the act, only four stations had research projects in home economics. The next year 36 stations

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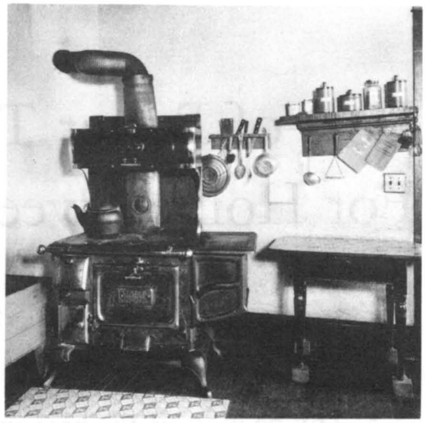


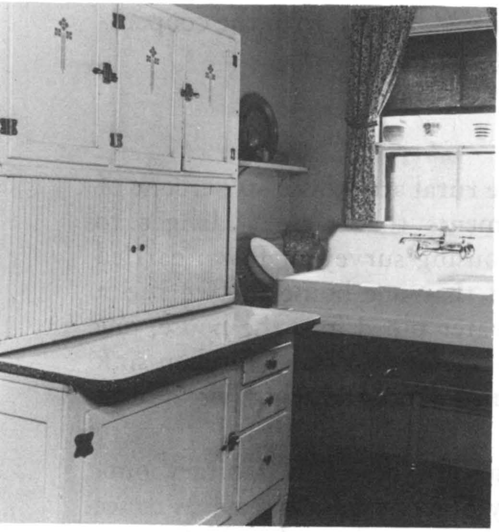
Above, portable respirometer used to measure energy expended on various household tasks. In this 1950's experiment, woman places pan in oven at many different heights, and energy for each height is recorded. Height which requires least exertion is best for the homemaker. Top right, stove or "cooking center" typical of those used in 1920's. Note table, which possibly as result of research has been elevated to proper height for homemaker, making her work less fatiguing. Right, modern kitchen. Range has continuous-clean oven panels.

had home economics projects and the stations had 65 new employees in home economics. The 20 years following the Purnell Act produced a revolution in American homes.

Studies of women's movements in cooking, washing dishes and ironing revealed that traditional cabinet, table and ironing board heights were all wrong—producing excessive fatigue and contributing to poor posture.

Research at the North Dakota, Washington, Oregon, Indiana and Vermont stations led to the planning of kitchens and the development of specifications so that cabinets, countertops, etc., could be mass produced as components for kitchens.

The pantry, and the "hoosier" cabinet of the turn of the cen-



Hoosier cabinets were miracles of convenience for homemakers. They provided a work area, storage, and usually a flour bin and sifter.

tury, became obsolete. The kitchen stove—whether wood, coal, kerosene, gas or electric—received a lot of research attention from stations in Indiana, Virginia, Nebraska, Maine and Kansas. It was found that many kerosene, electric and gas stoves were very inefficient users of energy. New designs for burners, for enclosures around burners, for ovens and for insulation were developed. These were quickly adopted by industry and incorporated into new models in the middle 1930's.

Similarly, studies on refrigeration were undertaken by numerous State stations, resulting not only in improved design and efficiency but in changes in homemaker practices. For example, the thrifty housewife used to cover the block of ice in her icebox with old newspapers to conserve ice. Experiment station research at Rhode Island and Indiana stations demonstrated that while this saved the ice it did not save the food.

In 1930, President Hoover called a National Conference on Home Building and Home Ownership. Experiment station workers served as chairmen of the Home Furnishings and Decoration Committee (Cornell), and Kitchens and other Work Centers (Wisconsin) Committees.

Results of experiment station research were presented in many papers and embodied in the reports and recommendations of committees. The conference produced an upsurge of interest in housing and probably stimulated the first national survey of housing, conducted in 1934. This was financed by the Civil Works Administration, and carried out under the direction of

the U. S. Department of Agriculture (USDA) with the cooperation of the State Experiment Stations.

Dangers to Health

The survey revealed that in some rural areas over 30 percent of the homes had sanitary arrangements that were a danger to health. An analysis of the 1934 housing survey in Iowa, carried out by the Iowa Station, revealed that one house in five had a bathroom, one in four had cold water piped into the house, one in eight had piped hot water, and one in two had a kitchen sink with a drain. Few homes had screened doors and windows; almost none were insulated.

These data provided the impetus for designing sanitary outhouses, followed by a campaign by State extension services to see that every home was provided with a sanitary outhouse. As a result of the interest of the wife of the U. S. President in this campaign, such facilities were sometimes called "Eleanors." A similar campaign was carried out to get families to install screening, at least in the kitchen.

The 1934 survey and subsequent research revealed that new housing in rural areas was usually not much better and sometimes inferior to older housing. The Experiment Stations recognized that there was a need for suitable plans at various cost levels, for minimum standards, and for the testing of construction materials.

Under the Research and Marketing Act of 1946, USDA's Agricultural Research Service coordinated the first Nation-wide survey of the kind and extent of activities in farm homes, and farm families' preferences in housing facilities. Forty-three State Experiment Stations cooperated in this study, which provided the basic research data on space requirements in homes. These were then translated into graphic standards for the use of architects and families.

During the 1920's, a large percentage of families in towns and cities were sending laundry to commercial laundries. Economists were predicting that home laundry functions, like spinning and weaving, were destined to be displaced in rural as well as urban areas.

Laundry was about the heaviest work of the rural housewife. A Nebraska study revealed that the average distance water was carried for laundry use was 62.5 feet, and that it took 46 min-

utes to carry enough water to do the family wash. In the absence of electricity on most farms, human muscle power cranked the wringer and perhaps a washing machine as well.

Lightening the Workload

Rural electrification was the only practical way to lighten the workload of the rural homemaker. Many stations—including Iowa, Kansas, Maine, Nebraska, Missouri and Michigan—had projects on developing unit electric plants for farms and for making the extension of central station power to rural areas economically feasible.

Testing of washing machines of various designs for efficiency in cleaning and wear on clothing was carried out by Washington, Indiana, and other stations.

Tests of electric irons at the Virginia station demonstrated that 1,000 watts capacity was necessary for maintaining a constant ironing temperature. They also showed that lightweight irons were as effective as heavier ones, and that temperature controls should be marked according to the kind of fabric to be ironed. These recommendations have all become standard in the appliance manufacturing industry.

In the 1920's, textiles and clothing were almost unexplored fields of research. The Texas Experiment Station was the first to establish a well-equipped textiles laboratory, and it retained leadership in this field for many years. In 1935 only a few stations had

Left, Fadeometer used in Ohio research projects on textiles, testing fabrics for color fastness to sunlight. Right, a flexible automatic washer provides precise amount of water needed for any size load, from big 18-pound dry load to just a single item.

adequate equipment for textile research. Before World War II, water-repellency, mildew resistance and wrinkle proofing were unknown. Most fabrics could be expected to shrink in use and laundering. The Research and Marketing Act of 1946 provided funds that greatly stimulated textile research.

In conjunction with textile research, the stations carried out research on the effects of various kinds of water and laundry materials on fabrics. When industry produced the first synthetic detergents in the 1930's, the stations tested them in various kinds of water and on various fabrics.

It was found that synthetic detergents eliminated the problem of soap-curd, a chemical reaction that created serious laundry problems in hard-water regions of the country. Synthetic detergents caused no more wear on garments than soap. These findings encouraged industry to market the new detergents.

Collection and analysis of body measurements for women and children completed in 1941 provided the basis for developing a practical and scientific system of sizing garments and patterns. This research was a national project carried out by the State Experiment Stations in cooperation with USDA.

The proposal for improved sizing of garments was accepted by the several branches of the apparel industry and served as the basis for the development of Commercial Standards of the U. S. Department of Commerce. They have been used as a guide by research workers in European countries.

Research in most of these areas continues as the changing lifestyles of families and new technologies create ever changing and developing needs. We are indebted to the State Experiment Stations in some degree for most of the comforts and conveniences we take for granted.

New Sciences Spring Up To Create Food "Miracles"

By Emil M. Mrak

Tremendous gains in food quality, and in freeing the housewife from long hours of drudgery preparing food in the home, have resulted from whole new fields of research that have sprung up within the lifetime of many present day Americans.

Preservation of food, such as it was, goes back many, many years in the history of man. For example, cave men are said to have preserved meat inadvertently by drying and smoking while hanging it over fire. Likewise, fermentation has long been in use for producing beverages and preserving certain foods—as in pickling. Use of salt as a preservative is lost in antiquity, too.

On the other hand, sterilization to preserve food is relatively new in man's history. It goes back only about 100 years to the time when Napoleon offered a prize to the person who would develop a new and better method of preservation. As a result, Appert used heat to sterilize food and then packed it in hermetically sealed containers, or in other words, developed the canning process as we know it today.

The great concern, of course, was only that food be preserved. Retention of the fine qualities of food, involving edibility, satisfaction and nutritive value, remained to be considered and studied by food scientists years later—and in fact mostly since the end of World War II.

As recently as 60 years ago, and prior to the development of modern and sophisticated means of handling and preservation, much of our food was distributed in bulk containers. There were relatively few small containers and the number available was meager, as compared with today's grocery store, which may well handle 8,000 or more individual items in small packaging.

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Common items were flour, sugar, dried fruits, smoked and salted meats and fish, dried products including fish, cereals and cereal products, legumes, fermented foods such as sauerkraut and pickles, coffee, and pastes.

Good and tasty fresh milk was a rarity. There were, of course, other dairy products, especially cheeses.

Fresh fruits and vegetables were not abundant so there was a stimulus for the development of food canning and freezing industries. Little, if any, consideration was given to factors which are so important to today's consumer, such as the acceptability of flavor, color, texture, convenience, nutritive value, safety, esthetics and diversity.

Changes in these areas started to take place following World War I and increased after World War II, side by side with the evolution of the field of food science and technology—a relatively new field of activity for Agricultural Experiment Stations, the U.S. Department of Agriculture (USDA), and industry. The greatest changes have taken place during the last 30 years.

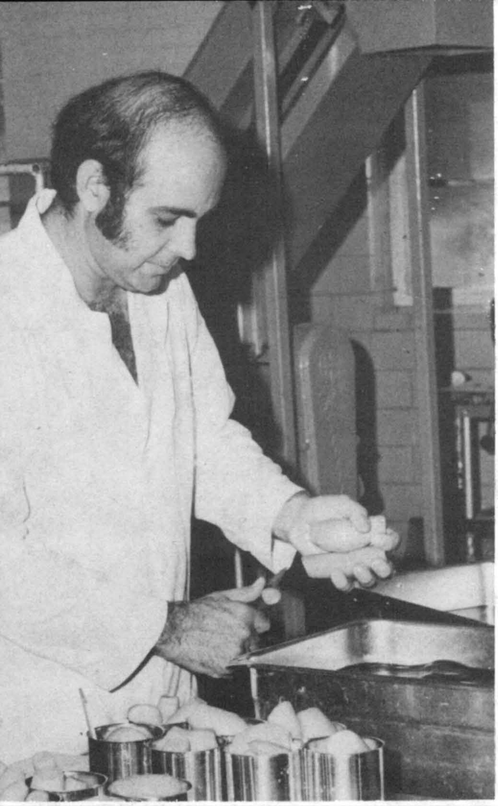
During this period great changes also have occurred in our style of living. For example, there has been a huge movement of people from farms to the cities. As a result, a large part of our population has lost contact with farm production, home preservation of food, and a knowledge of what can reasonably be expected of fresh or processed foods.

Pressure has been placed on processors and distributors to improve food in line with the consumer's preferences. But this was a very complex matter, requiring the skills and imagination of well trained food scientists, as well as laboratories and equipment. Such needs required a change in the philosophy and point of view of those experimenting with foods.

Early efforts of food scientists were concerned to a large extent with processing new varieties of fruits and vegetables, preventing spoilage, criteria of quality, utilization of surpluses, use of freezing as a method of preservation, the swelling of cans of certain pigmented fruits such as cherries and prunes, softening of cucumbers during pickling, and development of new products, such as canned fruit cocktail, fruit nectars, and various types of other beverages.

As time went on, however, the emphases changed and the research effort became more sophisticated to meet the needs and

Top left, motor store of 1920's. Top right, old-fashioned grocery store. Center, unrefrigerated meat in turn-of-century Minnesota meat market. Bottom, modern supermarket.



Louisiana food technologist checks canning quality of newly-developed yam variety with high resistance to soil rot. Jasper variety was found better for canning or baking than major variety now being produced. Jasper will make production possible on thousands of acres abandoned by Louisiana growers because of soil rot infestation.

wants of the consumer and his desire to improve his quality of life.

This, of course, has meant not only better and more acceptable foods, but also the transfer of an enormous amount of labor from the home kitchen to the processing plant. There has, indeed, been a revolution insofar as freeing the housewife from hours and hours of labor in the home.

No longer, for example, is it necessary for the housewife to bake her own bread, make her own cakes and pies, can her own fruits and vegetables, peel her own potatoes, pluck her own chickens, spend hours in preparing, salting and smoking her home grown meat, and making meat products such as sausage for future use. This removal of labor from the home to the factory has enabled the present day housewife to be free to do other things.

To consider and fulfill the desires and wants of the consumer, it was necessary to study a number of factors. These may be categorized as esthetics, acceptability, utility or convenience, stability or shelf life, safety, nutritive value, and cost. Such considerations may involve the improvement of old products or processes, or the development of new products or processes.


Right, in Nebraska research project, low priced cuts and scraps of pork are frozen, flaked, then formed into "logs" which are cut into identical sized servings. Left, flaked and formed pork not only is tasty, it also has eye appeal when cooked.

First and above all is the acceptability factor of food. This involves such things as taste and flavor, appearance, texture, feel, and crispness.

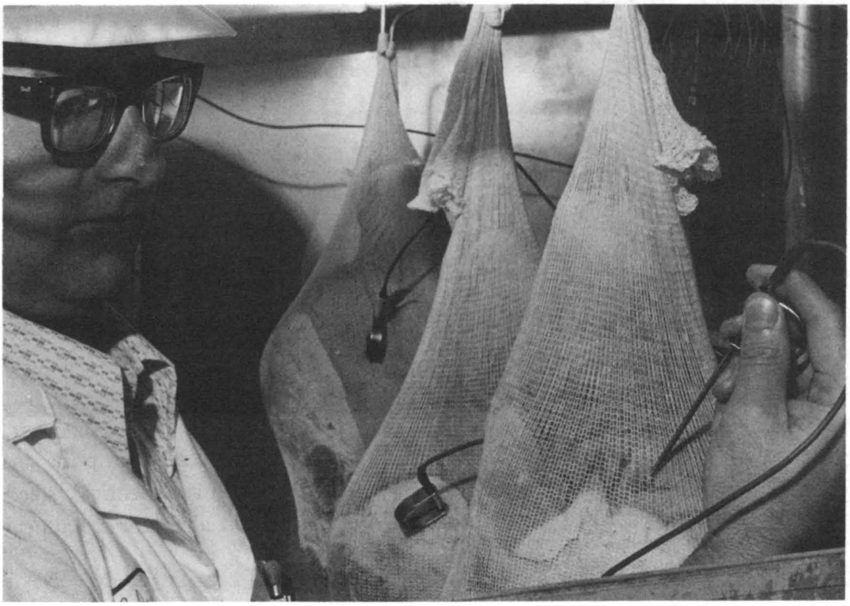
Retention of flavor during processing, storage, distribution, and use is not always easy to accomplish; great advances have been made along these lines with the result that today we have more flavorful foods than ever before. To accomplish these advances, the food scientist had to learn about the chemical and physical characteristics of many of the thousands of chemicals that make up the pleasant quality we term flavor. The flavor quality depends on the raw materials, their processing, and the handling of the processed product.

Taste Panels

Prior to World War II, little effort was directed toward flavor and taste testing of a product, whether it was fresh or preserved. Today, just about every experiment station, USDA, and industry use highly trained taste specialists in the laboratory and also consumer taste panels.

The second acceptability factor of great importance to the consumer and, of course, to the food scientist, is color. Whether we are willing to admit it or not, color and appearance are significant in the acceptability of food.

Strange as it may seem, color seems to enable the consumer to better appreciate the flavor of a product. As an example, an off-



Hams are tested for weight losses and tenderness during commercial processing, in Georgia-USDA research project. Here, temperature probes are put in place to insure temperature control.

color strawberry jelly seems to be less flavorful, even when fortified with flavor, than a product with an attractive strawberry color. In other words, there is a correlation between acceptability and color and flavor.

The third factor in acceptability is texture. We prefer that our meats be tender, our canned fruits and vegetables retain their characteristic form but not be fibrous, too firm or too soft. Certain products should have certain characteristics relating to texture, and great improvements have been made in processed foods along these lines. For example, by adding a small amount of calcium chloride, a harmless chemical, to canned whole tomatoes, good texture and form can be retained.

Over the years methods for measuring texture have been developed for all types of plant and animal products which enabled the food scientist to conduct studies and make improvements. Toughness, for example, is an important factor in meat texture. Studies of factors involved in the texture of meat has enabled the marketing of products with textures desired by the consumer.

One need only travel outside the United States to realize how

superior our foods are from the standpoint of texture to those provided elsewhere.

Feel of a product in the mouth is also a significant factor in acceptability. Peanut butter, for example, should have a desirable type of tackiness (stickiness) that is neither oily or pasty.

Noise indicating crispness likewise is important in products such as potato chips, celery, and nuts. To retain this desirable quality it has been necessary to develop special packaging and methods of handling in order to prevent moisture absorption by items such as potato chips, or on the other hand loss of moisture by fresh products such as celery.

The Pain Factor

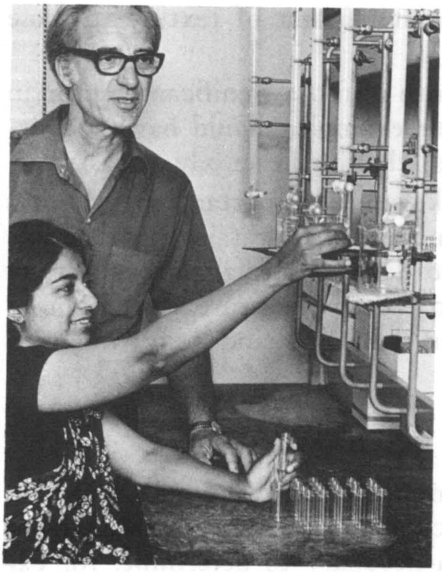
At times the food scientist must consider the pain factor in certain foods and this is particularly true of the so-called hot foods such as chili. It has been necessary to determine, for example, what part of the chili pepper and what types of peppers are involved in causing pain, how much a certain population desires, and so on.

As a matter of fact, on the market today are a diversity of pain producing foods and the consumer can purchase a product with the level of "heat" he desires. Control of this factor has involved a great deal of research and this came about as a result of the consumer's desires—some being mild, some medium, and some extremely "hot".

Other factors are involved in acceptability but those discussed above serve as examples of the complications and research involved in responding to the consumer's wants and desires.

During the past 20 years many convenience foods with a high utility value appeared on the market. These added greatly to our quality of life, for they do indeed minimize in many instances hours of labor in the home kitchen. Furthermore, in some instances they minimized kitchen failures. For example, most anyone should be able to make an angel food cake today by using cake mix.

Then again, no longer is it necessary to cut oranges in half, squeeze the juice out and then dispose of the waste, for today frozen orange juice concentrate is available. There also are such things as instant tea and coffee, instant mashed potatoes, and brown-and-serve biscuits. These take a tremendous amount of drudgery out of the home; they enable the consumer to have con-



Illinois food scientist and student.

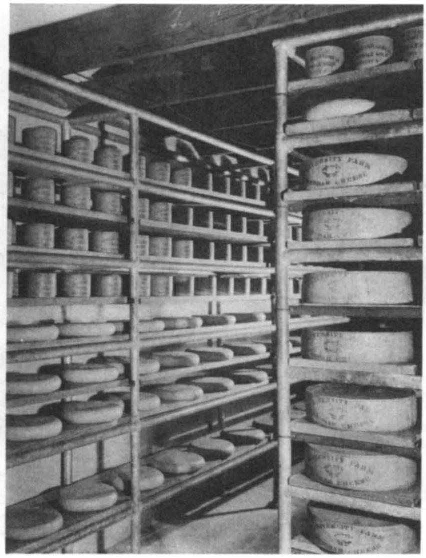
venience and diversity in food with a minimum of effort and a maximum of product quality.

If one surveys the grocery store today he finds a vast variety of dried, frozen, refrigerated, and canned convenience and prepared foods. They have all involved a great amount of research effort on the part of the food scientist, without which we would still be eating the bulk foods of a few years ago.

When the food scientist develops a product that is highly acceptable and convenient, he also must consider its stability or shelf life. Any product that deteriorates rapidly while in storage, in transit, on the consumer's shelf, or in his refrigerator is useless. The factor of stability, therefore, must be considered for every change made or new product developed. For example, it is common not to find rancidity occurring in fat-containing products such as cookies, nuts, shortening, and sausages.

Food research on fats and oils has enabled the inclusion of certain chemicals, termed antioxidants, which prevent or retard this type of fat deterioration.

There are those who indicate they would much rather have the materials free of these so-called antioxidants, but it is very doubtful if they would accept the repulsive odors and tastes of rancid fats. Furthermore, some believe that the products of rancidification are toxic, whereas the chemicals used to prevent rancidification have been approved as safe by the Food and Drug Administration.



Right, cheese curing room at University of California. Top, California winery.

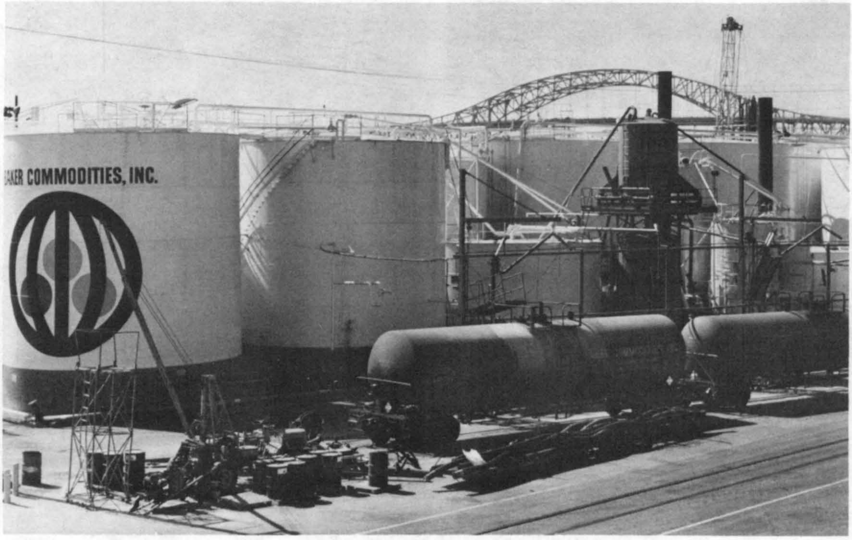
Another type of deterioration is the so-called "browning reaction" which occurs in highly concentrated foods such as sirups, dried fruits (particularly dried apricots, peaches and pears), and even in certain cereal and baked products.

During World War II an enormous amount of effort was devoted to the prevention and understanding of this type of deterioration which involves a change in some of the important carbohydrate materials, and frequently a loss of nutrients, texture and edibility. It was a particularly significant problem during the war because so many concentrated foods were shipped overseas.

Sometimes, however, this browning process is desired for the improvement of flavor and appearance. For example, we prefer the browned appearance and taste of toast and some people brown rice in the oven prior to boiling in water in order to obtain a "nutty" taste. When used in processed foods, the degree of browning is carefully controlled.

Changes also can occur in physical properties, such as the gelling properties of certain powders or concentrates. During World War II, dehydrated cranberries which were shipped overseas failed to rehydrate and gel satisfactorily because of deteriorative processes that took place while the cranberries were stored under adverse conditions. Today we know more about these degrading processes and how to prevent them.

Another deteriorative process known as the retrogradation of



Fats and oils are stored in tanks holding 29 million pounds at this California port terminal.

starch results in changes that the consumer may categorize as staling. This can occur in baked products, dehydrated potato flakes and powder, and other products rich in starch.

A great deal has been learned about this process and methods of preventing it. As a result, the consumer is seldom exposed today to products that have gone stale.

Quite often, loss of flavor can take place during storage. Canned fruits, for example, may be rich with fruity flavors when first packed. But if they are stored at undesirable and higher temperatures, the flavor component may decrease. With good handling after packing this loss of flavor is minimized.

Other forms of deterioration of foods involve microbial spoilage caused by yeast, bacteria and mold. Rarely do we see products undergoing this type spoilage anymore.

The most important aspects of this type of deterioration today involve organisms that produce toxic substances, particularly the bacteria that produce Botulinus and a number of molds that can produce the so-called aflatoxins which are carcinogenic (producing or tending to produce cancer).

As a result of intensive work in experiment stations, USDA, industrial laboratories and the Public Health Service, the occurrence of Botulinus was eliminated in this country except for

a very few occurrences. Steps have now been taken to assure complete elimination of the organism and its toxin.

Unique and important control procedures were developed to eliminate products that might be contaminated with aflatoxin producing mold. One such procedure involves the use of ultraviolet light to reveal the presence on shelled peanuts of a toxin-producing mold.

Insect infestation is another type of deterioration. At one time, flour, cereal, baked products, and dried fruits were quite frequently infested with insects. Improved packaging, fumigation and controlled storage conditions have pretty well eliminated such contamination.

Esthetics involves freedom from dirt, filth, and evidence of rodent and bird contamination. The use of modern sanitation equipment and chemicals, the maintenance of clean processing plants, premises and storages, and the use of improved packaging has virtually eliminated these contaminants.

Preserving Nutrients

Preservation of nutrients has received serious consideration by food scientists and experiment stations for many years. Handling raw materials, processing, storage, and distribution of processed products all affect the retention of nutrient qualities.

Nutrients involve not only various vitamins, but also certain mineral elements. The latter can be related to production in the field, but some might be lost during processing. Accordingly, process procedures today are used to minimize such losses. Vitamins, on the other hand, may decrease not only during processing, but also during subsequent handling.

Most of the processed food produced and distributed today has a high level of vitamin retention. In many instances, the retention of nutrients in processed foods is even higher than in fresh produce handled improperly.

Today nutritional labeling is in vogue, so some processors are indicating on the labels the nutritional values of their products. Such label information can only be based on a large number of analyses and in some instances has involved thousands of samples and very high expenditures. As nutritional labeling becomes more commonplace it is of increasing advantage to the consumer.

Studies on the enrichment of certain foods has led to vitamin and mineral enrichment of bakery items. Research on the pos-

sibility of including iron and enriching other foods is now underway.

Safety has already been discussed with respect to Botulinus and aflatoxins but there are other bacterial infections such as staphylococcus and streptococcus that have been extensively studied with respect to their control and the assurance of a safe food supply.

There are natural toxins such as ciguitera poison in certain fish, red tide organisms in certain clams, mussel poisoning, and a number of plant poisons that food scientists have eliminated in processed foods.

A great deal has been said about the occurrence of pesticides in foods. Some experiment stations have established research facilities to study the pesticide problem, not only from the standpoint of residues, tolerances and safety, but also in relation to the fate of these chemicals under various environmental conditions.

The Food and Drug Administration recently indicated that the areas of pesticides and food additives have received so much attention and study by all agencies that they have given a lower priority of concern to these chemicals than to microbial problems, nutritional labeling, and environmental contamination.

Food scientists also are concerned with cost, and accordingly experimentation directed toward the improvement of quality may well result in the reduction of cost.

Minimizing Pear Losses

For example, it was observed that if pears are harvested at specific stages of maturity, placed in a cold room at about 40° F for a period of time, and then brought into a maturation chamber at 80° to 90° F, all the fruit ripens at the same time with the result that losses from underripe or overripe pears are minimized.

When this procedure was first developed, it resulted in reduction of the cost of canned pears to such an extent that cost benefits could be and were passed on to the consumer.

Other procedures decreasing costs—besides processing—have been found in labor saving devices, in minimizing waste, and in improving utilization.

Many new products have appeared on the market since World War II. Some of these are convenience foods but others are entirely new and designed to meet the needs of our changing way of life and food habits. These cover the entire range of foods from meat products to canned fruits and vegetables.

Today there is so much concern about the environment that food scientists have found it necessary to consider utilization of waste products, and improved disposal methods, in order to prevent land and water contamination. This is a tremendous area and has resulted in improvement in the quality of life though at times it has been quite costly.

Ways With Whey

For example, disposal of whey, which is waste in the manufacture of cottage cheese, is causing increasing difficulties for manufacturers.

Large producers can afford equipment costing half a million dollars to dry the whey so it can be sold as a feed protein. But the equipment is too costly for small plants. Thus they may be forced out of business if they cannot meet environmental standards requiring whey to be pretreated before disposal in sewers or waterways.

The Oklahoma Agricultural Experiment Station is seeking new low-cost methods to convert whey into a protein feed, leaving the remaining whey clean enough for disposal. Scientists have found that yeast similar to that used in making bread or beer can break down the whey. The yeast uses the milk sugar and converts it into an edible protein.

Simple equipment already available in most plants can be used in the process. It usually requires about 12 hours to decompose consistently from 80 to 98 percent of the waste in laboratory tests.

As a result of the contributions of scientists we are eating more flavorful, safer, and diversified goods, easier to prepare and more nutritious and sanitary, than ever before. An amazing number of foods is available the year around at a lower part of our disposable income than any place else in the world. Much has been accomplished in a rather short period of time and the final result has been a greatly improved quality of life.

High Altitude Cooking, Baking: Some Tips for the Housewife

By Klaus Lorenz

Cooking and baking processes are affected by atmospheric pressure, as women of families settling in the high altitude region of the United States have found out. They discovered that it took considerably longer to cook such staples as potatoes and beans and that their favorite cake recipes, well balanced for use at sea level, produced cakes which would rise too high in the oven and then flow over the top of the pan.

The difference in atmospheric pressure is the cause of all these difficulties. As altitude increases, the air pressure becomes less. This has to be compensated for. Just as the pressure of water is greatest at the bottom of the sea and becomes lighter near its surface, so does the pressure of the atmosphere decrease as elevation increases.

Problems in high altitude food preparation are encountered in many states. Some states and cities where adjustments due to elevation have to be made are given in the table on page 283.

This high altitude region comprises more than one-third of the United States geographically. Although these areas are sparsely populated, about 15 million people make their home there.

Problems of high altitude food preparation have been studied for many years at Colorado State University. The equipment and the laboratory which make these investigations of the effects of altitude possible are shown in a photograph with this chapter. The laboratory itself is a steel cylinder seven feet in diameter and nine feet high. It can be ventilated and the temperature and humidity controlled.

Atmospheric pressure inside this laboratory can be adjusted and maintained to simulate altitudes between sea level and 12,000 feet.

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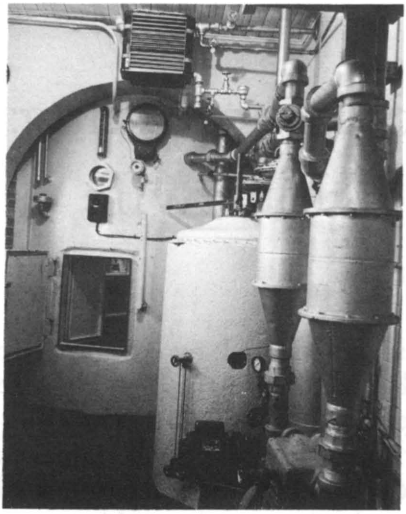


High altitude chamber used for Colorado studies on the effects of atmospheric pressure in food preparation.

The laboratory is equipped to conduct baking and cooking experiments at different elevations. This not only helps people in the high altitude region of the United States, but also makes it possible to respond to the many requests for information which are received every year from countries located in the high altitude regions of South America, Asia and Africa.

Essentially, three types of problems have to be considered when preparing foods at high elevations:

• The greater expansion of leavening gases which affects all baking processes

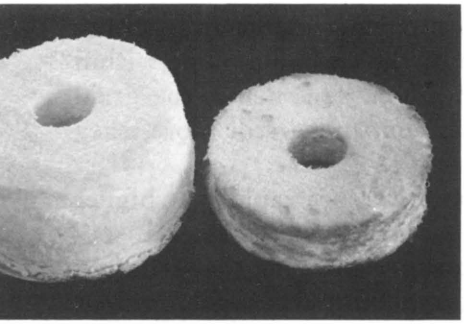
• The difference in temperature at which water boils, which affects both baking and cooking

• The faster rate of evaporation of moisture from foods at reduced atmospheric pressures

So Cakes Won't Fall

Since air pressure is less at higher elevations, the leavening gas in a cake batter expands more. So a correspondingly smaller weight of carbon dioxide or other leavening gas is required to perform the same amount of leavening as the atmospheric pressure decreases.

This applies to all baked products whether they are leavened with carbon dioxide, as in the case of cakes, baking powder biscuits, muffins, and quick breads; or with air, as in angel food and sponge cakes; or with steam, as in popovers and cream puffs.



Angel food cakes baked at 5,000 feet. Cake on left was baked from recipe adjusted for altitude. Cake at right was baked from a sea level recipe.

High Altitude Table of Cities and Towns

State	City	Elevation feet
Arizona	Tucson	2,390
	Flagstaff	6,886
Colorado	Boulder	5,347
	Colorado Springs	5,985
	Denver	5,309
	Fort Collins	4,994
	Pueblo	4,657
	Trinidad	5,982
Idaho	Boise	2,880
	Idaho Falls	4,742
Montana	Billings	3,117
	Bozeman	4,754
	Helena	4,108
Nebraska	North Platte	2,826
	Scotts Bluff	4,662
Nevada	Reno	4,484
New Mexico	Albuquerque	5,008
	Las Vegas	6,398
	Sante Fe	6,998
South Dakota	Rapid City	3,196
Texas	Amarillo	3,691
	El Paso	3,767
Utah	Ogden	4,307
	Salt Lake City	4,345
Wyoming	Casper	5,101
	Cheyenne	6,105
	Laramie	7,159

A cake's structure is very delicate, and increased pressure resulting from additional expansion of the carbon dioxide within the cells causes them to expand too much. This makes the grain of the cake coarse, or, if the cells are expanded still more, they will rupture and a fallen cake will result.

Liquid in a cake batter also evaporates more rapidly at higher elevations, causing the dissolved sugar in the cake batter to become more concentrated. Excessive sugar weakens the structure of the cell walls of a cake. Thus, reducing the sugar, and/or increasing the liquid slightly, provides stronger cake cell walls which are less likely to collapse.

Generally, no changes in formulation are required up to an elevation of approximately 2,500 feet. A cake recipe adjustment guide for elevations higher than 2,500 feet is given in a second table.

Cake Recipe Adjustment Guide for High Altitudes

Adjustment	3,000 feet	5,000 feet	7,000 feet
Reduce baking powder For each tsp., decrease	1/8 tsp.	1/8-1/4 tsp.	1/4 tsp.
Reduce sugar For each cup, decrease	0-1 tbsp.	0-2 tbsp.	1-3 tbsp.
Increase liquid For each cup, add	1-2 tbsp.	2-4 tbsp.	3-4 tbsp.

These suggestions for adjustment shown in the second table have been established through baking experiments with many different recipes at different elevations. But contrary to popular opinion, there are no set rules for modifying a cake recipe for higher elevations. Needed changes depend on the type of cake and relationship of the ingredients to each other. Quite frequently the proper recipe adjustments have to be worked out by trial and error using the suggestions in the second table as a starting point.

With biscuits, muffins, and quick breads, the baking powder may be decreased slightly, but structure of the products is such that it generally will stand the increased internal pressure at

higher elevations quite well. Cookies usually do not need adjustments for altitude, although a slight reduction in baking powder and sugar may improve them.

Cake doughnuts made from sea level recipes are frequently cracked, too high in fat absorption, and too compact and dark. To remedy this, decrease the leavening, sugar and fat.

Angel Food and Breads

In angel food cakes the leavening agent is air. At higher elevations the amount of air beaten into the batter will expand to a larger volume than at sea level and, therefore, less air is needed. Sugar in the recipe also should be reduced, and a higher baking temperature for a shorter time will generally give better results.

Cakes baked at 7,500 or 10,000 feet do not brown as much and as rapidly as cakes baked at sea level at the same oven temperature. Caramelization of sugar in the cake recipe is responsible for crust color formation and depends upon the temperature. The faster rate of evaporation at higher elevations causes a drop in temperature in the cake crust.

This temperature drop continues until the heat absorbed by water evaporation is equal to the heat transferred to the crust. The lower the atmospheric pressure, the lower the crust temperature. That accounts for the recommendation to increase the baking temperature to compensate for the reduction in crust temperature caused by evaporation.

For popovers, the amount of egg in the dough should be increased and the shortening reduced. This makes a stronger batter which will be able to retain the steam long enough for a crust to form. Popovers made by sea level recipes lose the steam too rapidly, both by expansion and evaporation, and turn out more like muffins.

A cream puff batter, being rather heavy, holds the steam well and does not require any corrections for altitude.

Baking of bread is affected by altitude just as the baking of cakes and sweet goods. However, fewer changes in the recipe, dough preparation and dough handling are required to adopt a bread recipe for baking at reduced atmospheric pressures.

Bread doughs rise more rapidly at high altitudes and may become overfermented or overproofed if not watched carefully. Less yeast may be used. However, most bakers and many housewives in the high altitude region prefer to decrease dough fermentation and proofing times rather than reducing the yeast.

Because flour dries out faster at high altitudes, it may be necessary to use more liquid to compensate for this loss and make the dough the proper consistency.

When a liquid is heated, vapor begins to form. The bubbles of vapor, being lighter than the liquid, rise upward, but they cannot reach the surface until the pressure within each bubble just exceeds the atmospheric pressure on the liquid's surface.

Temperature at which bubbles reach the surface and break is known as the boiling point. This is the temperature at which pressure of the saturated vapor within the liquid is equal to the outside atmospheric pressure on the surface of the liquid.

Since at high altitudes the atmospheric pressure is less, the pressure of the vapor necessary for the liquid to boil is less and will be reached at a lower temperature. For this reason, liquids boil at lower temperatures at high altitudes. Lowering of the boiling point of water amounts to about 1.9° F for each 1,000 feet increase in altitude, as seen in the table.

Boiling Temperatures of Water at Various Altitudes

Altitude (feet)	Boiling point of water: Degrees F	Degrees C
Sea Level	212.0	100.0
2,000	208.4	98.4
5,000	203.0	95.0
7,500	198.4	92.4
10,000	194.0	90.0

Time and Tenderness

Foods cooked in boiling water require a longer cooking time to become tender. It is difficult to give any definite cooking rules for vegetables since even with the same kind of vegetables, there are so many variations in size, variety, stage of maturity, and so on. In general, the time must be increased from 4 to 11 per cent per 1,000 feet, depending on the vegetable.

Eggs and meat, such as stews and pot roasts, must also be cooked for an increasingly longer period with higher altitude.

A pressure cooker is a great convenience at high altitudes for cooking meats, beans, and other vegetables which require relatively long cooking. By increasing the pressure, the tempera-

ture at which water boils is raised and the food is cooked more quickly.

However, the steam within the pressure cooker is also affected by the altitude. Boiling temperature of the water inside at 15 pounds pressure is not as high at 5,000 feet as it is at sea level.

To reach the same temperature, the pressure must be increased about 1 pound for each 2,000 feet of elevation. For example, at 5,000 feet a pressure of 17.5 pounds will give the same internal temperature as 15 pounds at sea level. If the pressure cooker has a gage graduated in 1-pound divisions, such an adjustment can be made easily.

Unfortunately, the gages of some pressure cookers do not go above 15 pounds; when using them, it may be necessary to lengthen the time given for cooking a particular food. An increase of 1 to 2 minutes is sufficient for most vegetables. Beets, whole potatoes, and sweet potatoes require about 5 minutes longer at 5,000 ft.

Canning is another phase of food preparation which is affected by the lower boiling temperature of water at high altitudes. The time needed to process fruits and acid vegetables in a hot water bath should be lengthened with increasing altitude.

Add one-half pound to the gage pressure for each additional 1,000 feet in altitude, as illustrated in the table below.

Steam Pressure at Different Elevations

Degrees F	Degrees C	Steam pressure (pounds) at an altitude of			
		Sea level	4,000 ft.	6,000 ft.	7,500 ft.
228	109	5	7	8	9
240	115	10	12	13	14
250	121	15	17	18	19
259	126	20	22	23	24

With this increase in pressure, the sea level processing times may be used satisfactorily.

Lowering of the boiling point because of high altitude also causes difficulty in making candy and frosting. If the old-fashioned cold water test is used (soft ball, hard ball, crack, and so on), the candy will be cooked to the proper consistency.

However, in recent years the candy thermometer has come into

widespread use since it is more exact and not subject to variations of individual judgment. It must be remembered that at high altitudes a sugar solution, like water, boils at a lower temperature. If sea-level directions are followed, the sirup will be too concentrated by the time the prescribed temperature is reached, and the resulting candy or frosting will be too hard.

Better results are obtained if for each 1,000 feet of altitude, the temperature is lowered 1.9° F. If desired, before making the candy, the exact boiling point of water may be determined, and the difference between it and 212° F subtracted from the temperature called for in the recipe. For example, if the boiling point of water at 5,000 feet on a particular day is 202.5°; then 212° — 202.5° = 9.5° is the correction. Suppose the temperature for fondant at sea level is 239°. In this case 239° — 9.5° = 229.5°, which is the temperature to be used for fondant at 5,000 ft.

When the boiling point of water is checked in this way, any day-to-day variations in atmospheric pressure caused by weather conditions will be compensated.

The same corrections used for candy-making should be applied to frostings.

If a thermometer is used in jelly-making, the same temperature corrections should also be used. By being aware of the problems of high altitude cooking and baking and making necessary adjustments, every housewife should succeed in the kitchen regardless of the altitude at which her home is located.

Colorado State University, through the Altitude Laboratory of the Department of Food Science and Nutrition in the College of Home Economics, has conducted research in high altitude food preparation for over 40 years. Some results of these studies are available in the bulletins *Mile-High Cakes, Quick Mixes, Basic Cookie Mixes for High Altitude, Making Yeast Breads at High Altitudes*, and *Wheat-Gluten-Egg and Milk-Free Recipes for Use at High Altitudes and Sea Level.* These may be obtained at a small cost through the Bulletin Room, Office of Printing and Publications, Colorado State University, Fort Collins, Colo. 80521.

Are We What We Eat? Nutrition and Health

By S. J. Ritchey

The saga of human nutrition and the improvement of human health in the United States is really reflected in the efforts of many scientists who believed that human performance and well being—whether mental or physical—depends primarily on what man eats.

We know much more about human nutrition than we did 100 years ago and we hear much more about health problems related to the consumption of foods. Tremendous progress has been made in agriculture production methods and in food science and technology to assure a safe, wholesome food supply for the American population. Scientists in the State Agricultural Experiment Stations have, most appropriately, provided a significant measure of leadership in these areas.

Progress in human nutrition may be measured best by the knowledge that many nutritional related problems have been conquered. Life expectancy of the average American has increased significantly from about 40 years of age at the turn of the century to approximately 70 years at the present time.

Deficiency diseases, such as rickets, goiter, pellagra and scurvy, have disappeared from the scene in most American communities. Advances in nutrition have improved the health of new-born children and provided the basis for avoiding anemia early in life and for normal growth and development of the child so that its full physical and mental potential can be attained.

The development of human nutrition in the setting of the Agricultural Experiment Stations and the land-grant universities is a most interesting story. Among leading States in this work were Wisconsin, New York, and California.

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Nutrition, a relatively new science, evolved from the basic sciences of chemistry and physiology. Very early investigators, primarily Europeans, initiated nutrition studies as they attempted to understand the physiological utilization of food in supporting the essential processes of life, including growth, reproduction and lactation.

Nutrition research moved to the United States as colleges and universities were organized, but the founding of the land grant institutions and the Agricultural Experiment Stations was the catalyst for systematic research.

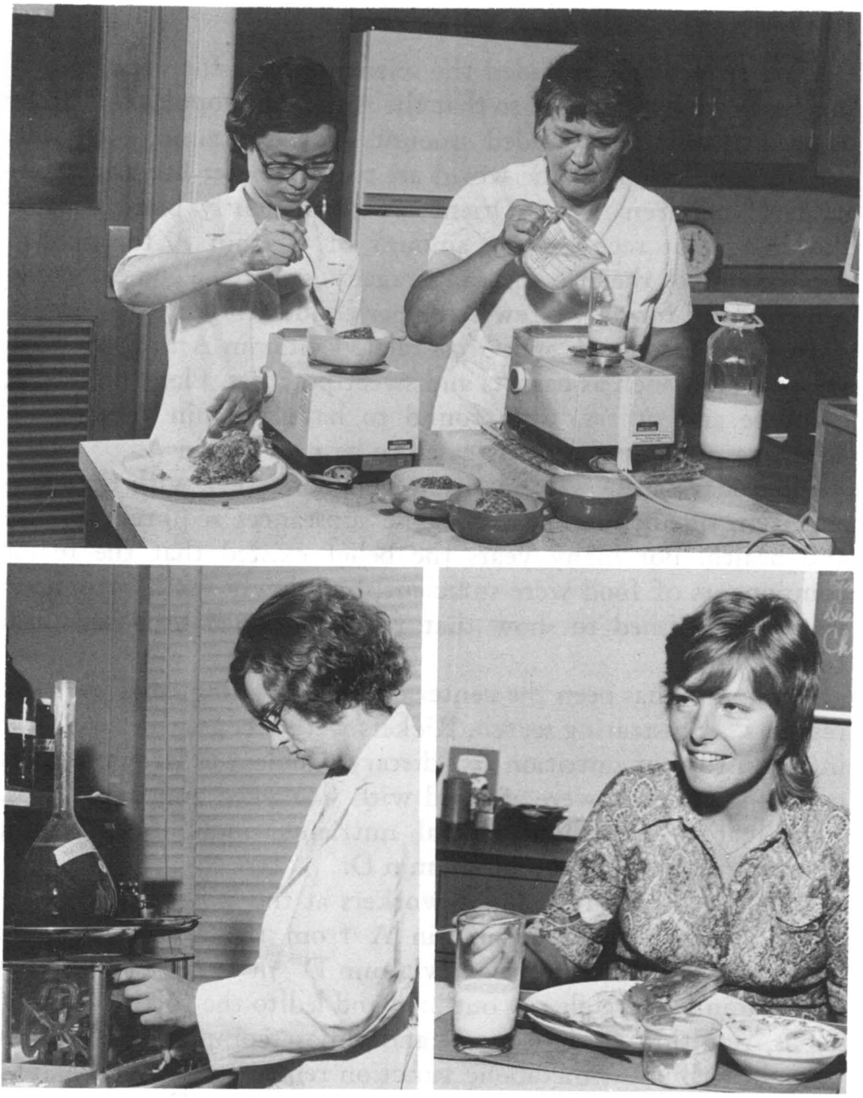
Agricultural research, in the form of nutritionists, chemists, and physiologists located in the animal and plant sciences, contributed a vast amount of knowledge basic to both human nutrition and food safety. Admittedly, their priority was enhancing the production capabilities of agriculture enterprises, but their basic contribution to human nutrition should be acknowledged.

The science of nutrition has progressed during the last 100 years from a meager understanding to the point that most of the essential nutrients seem to have been identified. Most nutrients have been isolated in purified form and the biological functions of many are reasonably well understood. Nutritionists have speculated that life could be sustained, although probably not enjoyed, through a supply of purified nutrients. But the search for ever more nutritional knowledge continues to be a fascinating story.

One of several pioneers was W. O. Atwater, director of the Connecticut Agricultural Experiment Station, who organized and became the first director of the Office of Experiment Stations in the U.S. Department of Agriculture (USDA).

Atwater was a leader in determining the components of food essential in meeting the physiological needs of men. Through the efforts of Atwater and his associates, a large number of basic foods were analyzed for groups of nutrients.

Our present food composition tables, the best known and most complete of which is *Agriculture Handbook No. 8* issued by USDA, are based upon this very early work. The handbook is currently being revised. Through the years, professionals in nutrition, dietetics, and related health sciences have depended upon these composition data. USDA continues to update and improve these food data, as the task is never-ending but essential. Information is provided from a wide variety of sources, including the experiment stations, USDA's laboratories, and private industry.



Ohio project seeks to determine effect of polyunsaturated ruminant fats on sterol balance of college women. Top, preparing food for diet study. Above right, eating diet meal. Above left, diet analysis.

Through a long series of studies in the early 1900's the nature of vitamins began to be uncovered. In 1914 McCollum and Davis at Wisconsin reported the discovery of vitamin A. This fat-soluble vitamin was related to night blindness in domestic animals and eventually was demonstrated to function in the regeneration of a pigment, visual purple, in the eye. That pigment is essential to normal sight in both man and animals.

This early work provided the scientific basis for supplementing foods with vitamin A so that the American population can be assured of obtaining needed amounts of the vitamin. However, not all populations in the world are so fortunate; literally thousands of children in the Orient are permanently blind because they have not received the amount of vitamin A for normal functioning of the eye. The real tragedy is that the condition can be prevented for only a few cents per child each year.

In 1919, Steenbock and Gross related vitamin A to foods with yellow color, such as carrots and sweet potatoes. Plant pigments, carotene and others, were found to have vitamin A activity. Later, carotene was demonstrated to be provitamin A.

Pioneer researchers in nutrition were concerned with the identification of all nutrients, or those substances required for life and health. For many years the belief existed that the major components of food were sufficient, but slowly experimentation was accomplished to show that food contained other essential compounds.

Vitamin D has been the center of an interesting, and, in many respects, a frustrating search. Rickets were recognized very early in the history of nutrition as a dietary problem as large numbers of young children were afflicted with weakened and bent limbs. Investigators implicated several nutrients, including calcium, phosphorus, vitamin A and vitamin D.

Elmer V. McCollum and coworkers at the Wisconsin Experiment Station separated vitamin A from the rickets curative agent and called the nutrient "vitamin D" in 1922. The benefits of vitamin D were clearly outlined and led to the fortification of foods, resulting in the control and almost complete eradication of rickets. But the metabolic function remained a mystery until very recently when H. F. DeLuca at Wisconsin, through a series of studies, unraveled the nature of this vitamin's activity.

Vitamin D is a clear example of the slow and sometimes tedious evolution of knowledge in nutrition, as well as in other sciences. Though the role of most nutrients is known, many facets of biological activity and the implications for human health and well-being are still under investigation.

Through studies by G. K. Davis at the Florida Experiment Station and others, knowledge of the inorganic elements in nutrition has advanced materially. The relationships of calcium and phosphorus to bone development, growth, and the prevention of

A western regional research project in nutrition used this mobile health laboratory during the late 1940's. Scene here in Oregon includes a physician and bacteriologist. Director of project is in dark dress in foreground.

rickets were recognized early in nutrition research in this country. But research with the trace elements, or those inorganic nutrients needed in very small amounts provides some interesting examples of valuable contributions.

Several nutrients such as protein, iron, folic acid, and vitamin B_{12} are important in the essential functions of oxygen transport and the control of nutritional anemias. As early as 1925, Hart and his associates at Wisconsin showed that a trace element, copper, was required for iron to be utilized in the synthesis of hemoglobin, the important oxygen transporter in the blood.

Zinc and Sex

Zinc was recognized as an essential nutrient in mammals in the 1920's by researchers at the Georgia and Alabama experiments stations. But the real impact in human populations has been recognized only in recent years. Dwarfism and impaired development of the sex organs of the male were identified in several population groups around the world. Eventually, these maladies responded to supplementation of zinc so that sexual development and growth was restored in the children.

Zinc is now recognized as an essential element for the human and a daily allowance was recommended for the first time in 1973. The recommended intake for children is based upon research accomplished at the Virginia Agricultural Experiment Station.

Perhaps no nutrient has been as controversial as fluorine, now recognized by nutritionists and by public health officials as important in lowering the incidence of dental caries or tooth decay. Several investigators from experiment stations in Arizona, Michigan, New York and Wisconsin are instrumental in proving that fluorine was active in mottled tooth enamel, an unsightly condition found in populations with water supplies containing 6 to 8 parts per million of fluorine.

Studies by these and many others led to the accepted concept that fluorine, at concentrations of about one part per million in the water supply, will reduce significantly the amount of dental caries in the population.

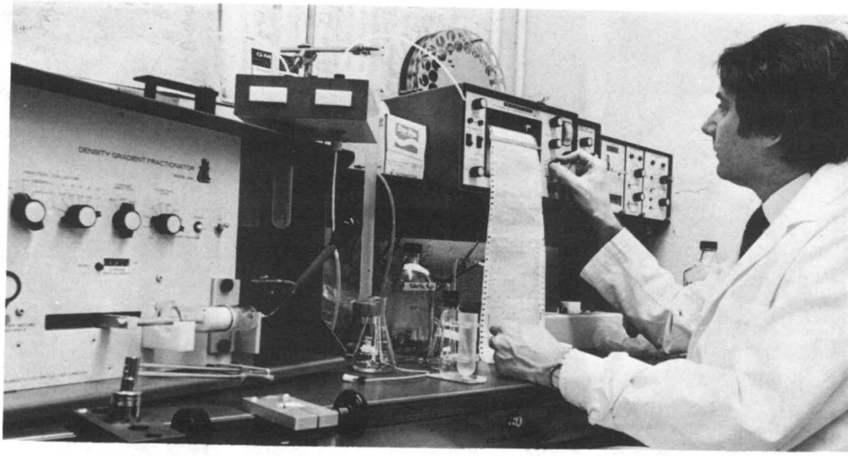
The saga of niacin, one of the water-soluble vitamins, is most important because it portrays the immediate application of information from basic research to the solution of human problems. Work at the Wisconsin Experiment Station, together with that of Goldberger and associates, showed that blacktongue in dogs was analogous to pellagra in the human and the two maladies could be cured by the same dietary supplements.

Ending the South's Pellagra

During the early part of this century, pellagra was rampant in the southeastern United States where the major staple was corn. Application of information from the basic research led to fortification of corn products available through normal market channels. Pellagra was eradicated in the region.

Since World War II, nutrition scientists have recognized that protein malnutrition is a major problem in many parts of the world. Researchers from many disciplines have focused their attention on improving the quantity and quality of protein in foods.

Scientists in the experiment stations and at land grant universities made key contributions to our present knowledge about protein nutrition. Certain amino acids, the components of proteins, were found to be essential in the diet of man by W. C. Rose in the 1940's and early 1950's. Dietary needs for these essential nutrients were described from studies by Rose at Illinois and by Ruth Leverton at the Nebraska Experiment Station.



Wisconsin molecular biologist developing laboratory procedures for quickly finding varieties of bean seeds high in total protein and methionine.

This work evolved from earlier classification of dietary proteins into animal and plant sources or into first and second class proteins based upon the capability to support growth and other vital processes.

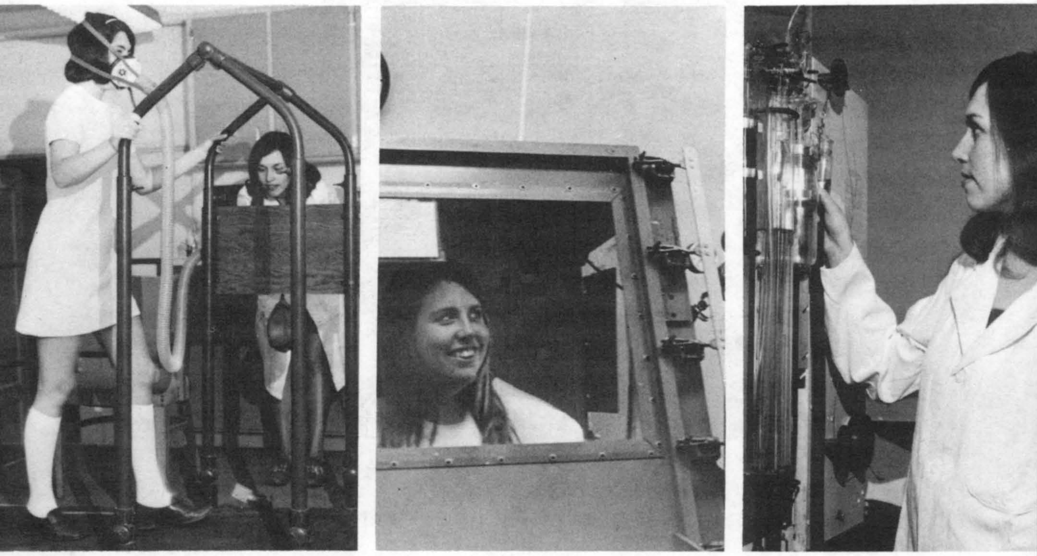
J. B. Allison at Rutgers, in New Jersey, and H. H. Mitchell, Illinois, were among the investigators who defined the biological role and the efficiency of utilization of protein in several species, including man. These studies became the basis for initiating programs to alleviate protein malnutrition in the developing countries of the world.

Considerable progress has been made in nutrition research through a mechanism unique to the Agricultural Experiment Station system. This approach, known as region research, brings together researchers from several states to work on common problems.

School Age Nutrition

An outstanding example is the series of studies designed to define the nutritional needs of preadolescent children. These studies, accomplished by personnel in the Southern region, represent the most comprehensive research about nutrition of the school age child. The focus has been on protein, but data on vitamins, minerals, fats, energy and numerous interrelationships have come from these studies.

Recommendations for protein needs of the growing child, based upon balance studies in which a range of diets varying in



Iowa studies energy metabolism and utilization of nutrients by women: Left, collecting respiratory gases during controlled exercises on treadmill. Center, helium chamber measures body volume so percent of body fat can be estimated. Right, analyzing gases.

protein level and composition were fed, have come from the regional work. Investigators have provided data for loss of protein through the skin of the growing child. These data have proved useful in establishing realistic guidelines for populations in many parts of the world.

Researchers in schools and colleges of home economics within the experiment stations have provided significant leadership in understanding the dietary habits of people and in applying fundamental information to people. A regional research project in the North Central region concerned with food consumption behavior of children is an excellent example of this type of research. A research project is currently underway in the Southern region to relate the food habits to growth, development and nutritional health of growing children. A study in the Northeast is determining nutritional needs during critical periods in human development.

Although human nutrition is only one small part of the total research program in the Agricultural Experiment Stations, important contributions continue to be forthcoming. A major advantage for applied work in human nutrition in the experiment station environment is the possibility of close coordination of re-

Top and left, Nebraska nutrition research. Right, subject of an Illinois infant feeding study acquiring technique of "test-weighing" her infant. Test-weighing is used to determine amount of human milk consumed by infant at each feeding.

search with disciplines involved in the production of food. Teams of researchers can work on production yields, genetic improvement of crops, and utilization of these products for human consumption.

The team effort at the University of Nebraska where investigators from agronomy and human nutrition are cooperating to study the use of cereal grain by human subjects is an example. Feeding the world population and achieving optimum health must involve many scientists from a wide range of disciplines.

The relatively new science of human nutrition will continue

to make significant contributions to the American population. There is much that is known, but much, much more is yet to be discovered and tremendous problems need to be solved.

The nutrition scientist knows relatively little about nutritional requirements of man throughout the life cycle. There is knowledge that nutrition makes a real difference in the health and well-being of the growing child, but few data are available from research laboratories. The impact of nutrition on human longevity is by and large speculative at this point in time. Control of obesity, diabetes, hypertension and other nutritionally related problems is important in our society.

Numerous other problems confront the nutritionist working in applied programs with the infant, the school-age child, the pregnant teenager, the obese middle-age male, and the elderly. Answers to many of their questions depend upon research in the Agricultural Experiment Stations and other agencies concerned with human nutrition and health.

Those nutritionists in the experiment stations and land grant universities have a rich heritage and a tremendous challenge as they, along with scientists in other disciplines and in other institutions and agencies, face the future.

Co–ops and the Stations, Partners in Progress

By Vernon E. Schneider and Beryle Stanton

About a half century ago, with experiment stations already into their fifth decade, the stations and the agricultural cooperatives began a productive partnership to help this country's agriculture upgrade itself in the course of its task of providing food and fiber to the U.S. consumer and the world.

Experiment stations already were hard at work on this goal. But farmers were just beginning to see the shape of the cooperative businesses they built into strong marketing and supply adjuncts to their on-farm enterprises over the next 50 years—the farmer-owned businesses that now do about $30 billion worth of business a year.

Farmers have benefited greatly through lower production costs, higher yields, more efficient animal gains, technological and pricing efficiency in the marketplace, and improved profit incentives.

However, the rewards of creativity, discovery and innovation in agriculture extend far beyond the farm gate. Many of these benefits have flowed directly back to society, which pays much of the bill in the first place. Benefits to consumers include: (1) An abundant supply of food and fiber available the year round, (2) High quality, pure foods, (3) Reasonably priced food and fiber, and (4) A variety of convenience food and fiber products.

Farmers made a few erratic explorations into "group action" during the 1800's, with all but a few of these failing due to a lack of understanding and experience on the part of farmers and the public alike. The few that began to succeed in the late 1800's and early 1900's were forerunners of cooperatives owning such famous food labels as Sunkist citrus and Dairylea dairy products.

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Station staff worked closely with many ventures and watched both the successes and the failures.

Western Farmers Association (WFA), Seattle, Wash., credits the Washington State College (now University) with being its father. W. A. Linklater, then director of the Western Washington Experiment Station, called the first and second meetings of farmers in 1917 to discuss forming a co-op. These resulted in the organization of WFA.

J. W. Kalkus, who succeeded Linklater, served as a director at large to WFA for about 30 years and continued to help formulate policies and programs of this supply and marketing organization.

The station also worked closely with WFA in its early marketing—developing egg and fryer marketing programs that later became patterns for much of the industry across the country.

It was also nearly half a century ago that some university and experiment station people began to take action to get farmers to move faster in adopting the practices and improvements they were recommending.

Representative of this group was D. W. Brooks, then a professor at the University of Georgia. He recalls that one of his main motivations for leaving this position some 40 years ago was to start a cooperative, a tool he thought could move station research on to farmers faster.

He also saw a co-op as a way to get action on the part of the individual farmer. So he became one of the founders of what is now Gold Kist Inc., an Atlanta-based cooperative providing farmers in a number of southeastern States with marketing and supply services.

Prizes for Best Yields

Brooks reports there have been hundreds of instances of productive partnership between Gold Kist and experiment stations in this region. An early example he cites is the Hundred-Bushel-Per-Acre Corn Project. In the early thirties, Georgia corn yield was only about 10½ bushels an acre, just as it had been for some 50 years.

Under the corn project, stations first ran tests to see if hundred-bushel yields were possible . . . and found they were. Then county agents and vocational agricultural teachers in each county started programs with 4-H and Future Farmers of America groups as well as with adult farmers.

The Georgia-based co-op helped finance these programs by giving prizes for the best yields to counties and to individual

farmers and stimulating action through publicity and in other ways.

This project, active for many years, did get some hundred-bushel yields and brought the average yield up to 60 bushels.

One of the main reasons for forming the Southern States Cooperative, Richmond, Va., in 1923 also was to carry experiment station research results and recommendations more quickly to farmers.

The Virginia Experiment Station, after long research, had announced that failures of clover and alfalfa crops were caused by farmers having to use seed not adapted to the State's soil and climate conditions.

W. G. Wysor, key founder and general manager of the co-op during its first 25 years, often told how Southern States came into the picture. It took the station findings on Williamsburg alfalfa that showed it a regionally adapted variety and began to promote it.

But the co-op wasn't able to find persons with enough interest and capital to take the new and improved strains of foundation stock seed coming from the station and make it available in large enough quantities for the farmer to use.

So it began to take foundation seed stock and place it in the hands of established farmer-growers in areas best suited to multiply the seed.

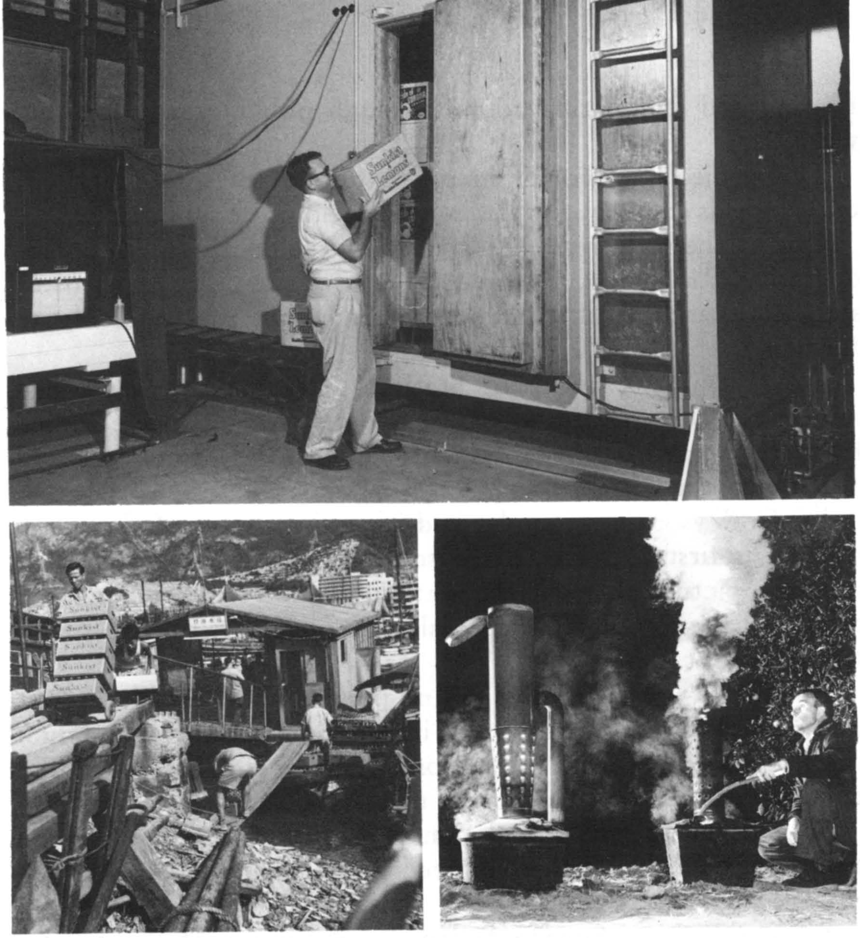
From this start, farmers began to get enough of the recommended variety to produce a better yielding crop.

Since these earlier days, experiment stations and co-ops have worked together in many ways and have maintained a close linkage as they moved ahead with the common purpose of improving this country's production of food and fiber for the good of all.

Stations have continued over the years to feed information to co-ops along with their other outlets. Here are two examples.

The California and Arizona stations provide Sunkist Growers, Sherman Oaks, Calif., with information for its members on cultural practices, pest control, varietal improvements, havesting and handling techniques, decay control, and economic information. Grower members use a return stack heater that the California station developed to reduce pollution from smudge smoke.

The Louisiana Experiment Station studied comparative rates of payout for broiler contract growers and contractors. It found that growers might not be able to form a co-op or other type of business because of the large amount of capital required for a



Top, California scientists and Sunkist Growers co-op worked together to study decay injury to citrus fruit in transit, using a half-sized railroad refrigerator car. Left, ferry carrying Sunkist brand soft drink to Hong Kong market. Right, California researchers reduced pollution from smudge smoke in orchards by developing an improved heater. It returns most of smoke to tank below for reburning.

broiler complex and the high risks involved. In many cases, a financial disaster was averted as the result of research findings.

Co-ops also work with stations to get valid and tested research information that farmers must have to meet consumer needs and expectations—with experiment stations as the basic information resource.

Landmark Inc., Columbus, Ohio, constantly seeks information from stations so its people at both State and local levels have reliable advice for farmers. Its binder of semi-technical information, Agro-Guide, has station findings as its nucleus.

This co-op also uses station research results and staff in its

yearly seed and fertilizer schools which train field representatives. Co-op personnel then relay the information on to farmers as they do business with them on a regular basis.

Plains Cotton Cooperative Association, Lubbock, Texas, reports big dividends have resulted for its members because Texas experiment stations developed varieties of castors (castor-oil plants) and sunflowers adapted to regional growing conditions. This added new cash crops in the area and provided consumers with still another source of quality protein and oil.

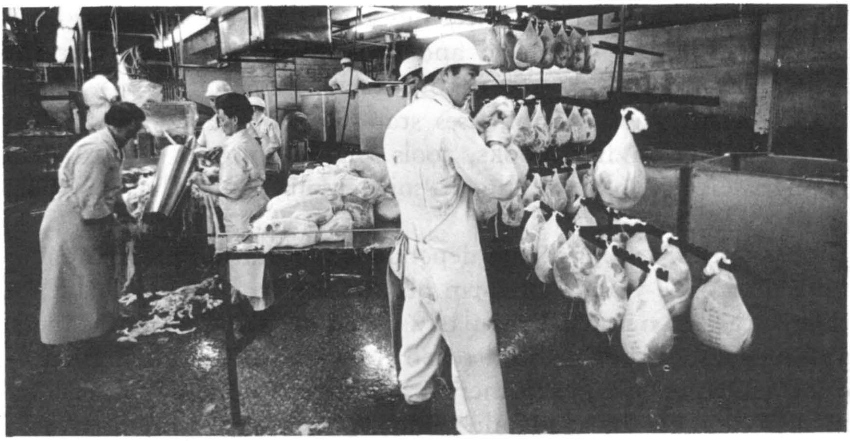
Farmland Industries, Kansas City, Mo., keeps in close touch with station work in the 15 States where it serves its members in the Midwest. Its staff, fieldmen, and merchandisers discuss, review, and observe stations' work on fertilizer, agricultural chemicals, and agronomic practices, and get research information on to farmers.

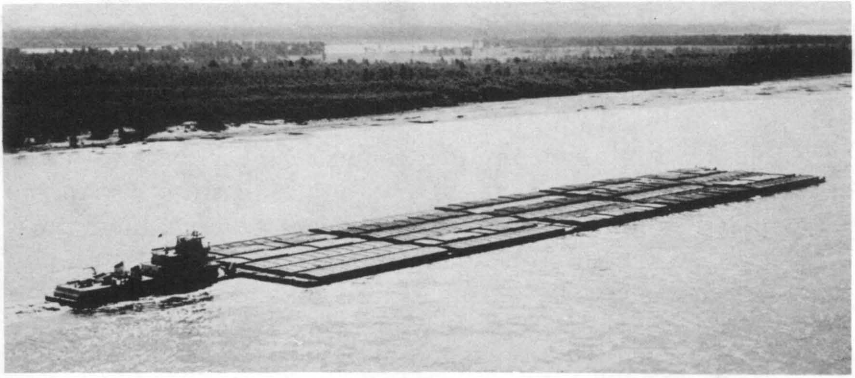
Farmland also carries station information to the nearly half a million farmers in its membership through local meetings, person-to-person advice, and its many publications that include a bi-monthly newspaper with over half a million circulation.

Gold Kist found in its earlier days that fertilizer available to farmers in the Southeast wasn't giving good results and the amounts recommended for use were very high.

So the co-op asked stations to run tests on kinds and quantities that would be most effective. It then worked with the stations to move test results on to farmers. And it began to get the kinds of fertilizer recommended by having cooperatively-owned plants

Co-ops such as Farmland help market hogs closer to consumer. Farmland operates this pork processing plant in Iowa.





Above, grain-filled barges being pushed down Mississippi River by co-op towboat, to return with fertilizer. Missouri Farmers Association shares in ownership of barge co-op. Right, co-op egg circle of 1919 receiving and paying for eggs.

produce it. Thus, the stations and the co-op together helped to reduce the farmer's costs, to increase his productivity, and to hold down food costs.

MFA Oil Company and Missouri Farmers Association, Columbia, conduct hundreds of meetings each year for farmers. Both Missouri experiment station and cooperative specialists present information here that stems from station research.

Cenex, St. Paul, Minn., uses station recommendations in its crop production handbooks, tools that employees use to help farmers with crop management, soil fertility, and other practices and problems.

Many other co-ops report dependence on station recommendations on a wide variety of farm production matters for information carried in manuals; regularly issued newsletters, newspapers, and magazines that in total reach most of the agricultural producers in this country; farmers production guides; and consumer information on the availability and cost of various food items.

Experiment stations get additional funds from co-ops to do both specific and general research—with co-ops the financial supporters of research. These private funds supplement public funds for the good of all.

Agway Inc., Syracuse, N.Y., has a heritage of cooperation with land grant universities and stations, a legacy from its three founding co-ops that has remained strong. It provided almost $200,000 for more than 90 agricultural research projects during the past year. This included regular grants-in-aid of $149,000 to 15 universities and $50,000 for a dairy chore reduction program.

Since Agway's formation in 1964 by the merger of three co-ops in the Northeast, it has invested over $1 million in grants-in-aid that are aimed at improving farm income and consumer satisfaction.

The dairy chore reduction program, coordinated by Agway, is a concerted effort now going on to make dairying more profitable, safer, and more pleasant. Dairymen and representatives of land grant universities, businesses involved in dairying, and Agway met several times to identify major problems in dairy housing, feeding, milking, and manure management.

Then funds from Agway, equipment manufacturers, dairy co-ops, banks, and others serving dairymen went to support about 25 specific projects under way at 12 universities.

From time to time, Gold Kist provides funds to stations—for example, for work on coastal bermuda grass. The cooperative provided fertilizer so testing could continue after appropriation funds ran out. Proper fertilization increased productivity up to some 12 to 14 tons an acre under ideal conditions, and as yield went up so did protein content and nutritive value.

Cenex (Farmers Union Central Exchange) has provided a number of financial grants-in-aid to stations. For example:

• For studies by the South Dakota Experiment Station in 1964 which showed that bulk handling of fertilizer, then in its beginning stages, was both agronomically and economically feasible

• To North Dakota State University in 1968 making it possible for the experiment station to complete a badly needed greenhouse

• For a study in 1969 at the Wisconsin Experiment Station which resulted in programming and computerizing plant analysis results for rapid interpretation and recommendations. Plant analysis is now an integral part of Cenex' Crop Monitor service to its farmer members

Western Farmers Association is a supporter at the State legislature for experiment station funding and also makes special contributions for specific projects.

For the past ten years, Farmland Industries has provided funds for about 15 graduate students a year to work on specific studies of interest to both the station and the co-op. It has also supported work at Colorado State University that led to a new method of soils analysis.

Ohio State University frequently gets seed from Landmark at no cost for research. In 1973–74, it was using one of the co-op's hybrid corn varieties in no-tillage experiments and a high yield demonstration.

Co-ops move experiment station findings out of the research realm and experimental stage and put them into actual use—with co-ops becoming the delivery system in many cases.

Station findings help keep a new computer planned cropping system of Landmark current. Called ComputerCrop, this system of crop production recommendations by use of the computer starts with soil tests and surveys, then makes recommendations for the individual farmer on tillage, seed, fertilizer, weed control, insect control, and cost analyses.

Nutrition Information

Many co-ops keep in close contact with station staffs to get information and help on nutrition, techniques for processing, quality control, new products, and other material vital to process and market farm products in the best interest of both producers and consumers.

A progress report from an Oklahoma experiment station project showed many co-ops in that State were not retiring farmer equities on a regular basis. The study is now evaluating the effectiveness of existing and/or alternative plans for retiring equities and their effect on co-op operation.

Farmland Industries cooperates in field tests of experiment station findings and uses results to develop products and services for members. It says, "Whenever we consider a venture into a new area, we discuss its advisability with experiment station and university people."

Station and university people serve on Farmland's advisory committees on fertilizer, feed, and agricultural chemicals. In general, each committee has a representative from each university in the region served.

Station staffs and representatives of several regional co-ops—Tennessee Farmers Cooperative, FS Services, Southern Farm Association, Landmark, Southern States Cooperative, and Gold Kist—hold conference board meetings regularly to report to each other and to discuss mutual problems and progress in dairy, livestock, and poultry fields.

Stations in the States served by Gold Kist work closely with the co-op's research staffs through College Feed Boards. The groups meet twice a year, with the co-op handling expenses, to exchange and compare research results.

The Oklahoma Agricultural Experiment Station has research in progress that is evaluating marketing patterns and coordinating arrangements in marketing grain from farm producers on through country elevators and up to existing regional co-ops.

The Louisiana station is conducting a project that has already resulted in establishment of a farmer-owned poultry processing and marketing co-op.

Nine universities were involved in a recent study on the Associated Standby Pool Cooperative. This came up with a general evaluation and some recommendations on how the 17 member dairy cooperatives in this Pool could better use it to support reserve supplies of grade A milk on a year-round basis.

Thirteen stations in the North Central Region and agencies of the U.S. Department of Agriculture (USDA) are participating in a study on adjustments by dairy marketing co-ops in the region. The Ohio station has been analyzing costs, effect on in-store promotion techniques, and labor productivity in about 65 dairy associations. Preliminary findings of this study analyzed a wide range of adjustments being made and their effect on dairymen and their co-ops as well as the parallel question of the impact of growth and size of good retailers upon co-ops.

Iowa's contributing project in this broad study is on alternative solutions for regionals. Data has been developed on production and costs of various services for members or for milk bottlers by fluid milk bargaining co-ops, and an analytical procedure and systematic method to determine the most effective routing of trucks to move members' milk to plants has been selected.

Kentucky's part of the study shows that problems of price, producer equities, and market stability arise from differences in marketing activities and related service costs.

Illinois is collecting information from dairy co-ops to determine the cost of providing co-op services, who pay for them, and who benefits from the services.

Other studies in the dairy area include:

In Connecticut, results of research analysis have helped make decisions on pricing policies and programs by a new co-op in the Northeast, Regional Common Marketing Agency, that serves a number of dairy co-ops.

Stations in Maine and Vermont are working with Yankee Milk, Newington, Conn., to assess the impact of extending the Boston Regional Federal Order into northern New England.

Pennsylvania has done research on the share of the market by co-ops, food firms, and proprietary firms. It shows that local independent firms handle a larger share of fluid milk than in many other areas of the country.

Since Wisconsin leads the nation in milk sales, much research has been done on dairy co-ops there. In 1960, a research team developed a blueprint on the best type organization for the industry which demonstrated that reorganization could yield farmers 10 to 25 cents more per hundredweight of milk sold.

Followup studies dealt with ways to bring about changes such as plant and management efficiencies, consolidation possibilities, membership information programs, and arrangements for more effective bargaining.

This research contributed significantly to the combining of over 100 Wisconsin dairy co-ops, thus improving the income of members and holding down the costs of moving dairy products to consumers.

Minnesota has been conducting a major study of market structure, conduct and performance of selected agricultural product and supply markets in that State. In about 950 marketing and supply co-ops, it has examined relationships of concentration, product diversification, and degree of vertical integration with such performance measures as profitability and technical efficiency.

The study is showing consolidations into fewer and larger co-ops that are more diversified and more vertically integrated both forward toward market and back toward the sources of farm input raw materials than was true 20 years ago.

Other studies in the business area include:

• Finding the economic impact of various mergers of cooperative cotton gins, by the New Mexico station

• Developing accounting systems and ratio analysis for co-op decision making, by the Arkansas station. Early findings indicate that in some cases farmers would not have an access to market for certain of their commodities without co-ops

• Studying the economics of organizing, financing, and operating co-ops, by the Georgia station. One aspect is appraisal of the co-op as an alternative form of business enterprise. Another is exploring specific business situations that seem to call for a multiple owner firm or a co-op

Co-ops at times take experiment station results a few steps farther along in the research process, testing them further—with the co-ops acting as applied researchers.

Many techniques developed by stations in breeding new varieties are used by Farmers Forage Research, a research co-op, on its seed research farm. It also uses station specialists as consultants on specific projects.

Purdue University helps the Indiana Farm Bureau Cooperative Association with its poultry breeding farm. Experiment station research is further extended by Gold Kist—on its own research farms for broilers, eggs, pork, and beef.

Agway's Farm Research Center is working with Cornell University and USDA's Agricultural Research Service on drying manure from poultry to the point where the odor is almost eliminated.

Waste Control

The experiment station at the University of Missouri helped set up the 1,200-acre research farm of the Missouri Farmers Association, Columbia. It helped the farm design a complete system of waste control. The cooperative farm also adopted and adapted a number of crop and livestock production ideas, with university assistance, for further testing.

The future holds even greater promise of a fruitful relationship between the experiment stations and the co-ops. As in the past, goals of this partnership will be to: (1) preserve and strengthen the independent commercial farmers, (2) provide the public with an adequate supply of high quality food and fiber, and (3) make sure that the benefits on the investment of public funds in agricultural research outweigh the cost to the public.

Future trends include:

—Greater emphasis on cooperative marketing.

—Even greater coordination of experiment station and private cooperative research, with duplication reduced or eliminated where possible.

—Greater involvement of co-op personnel in planning experiment station research.

—Improvement of the delivery system to transfer experiment station results to practical use by farmers, directly and through their co-ops.

—While much of the work will continue to be between State experiment stations and co-ops within the State, more regional and national coordination of programs of research is needed.

NEW BUSINESS

George Harrar Sets Off The Green Revolution

BY IRENE URIBE

In June 1942 J. George Harrar had just completed his first year as Head of the Department of Plant Pathology at Washington State University. He had come to Washington State from Virginia Polytechnic Institute, where in six years he had attained the rank of full professor. Now he was head of an Agricultural Experiment Station's division of plant pathology with responsibilities in coordinating his department's research, teaching and extension activities.

Harrar was young, forceful, popular on campus. A sportsman and former college athlete, he was as happy in a duck blind at sunup as in the laboratory or lecture hall. Some ten years back he had spent four years teaching at the University of Puerto Rico, where he acquired a command of Spanish.

That spring the Rockefeller Foundation was looking for just such a man—a highly qualified scientist, fluent in Spanish and acquainted with Latin American culture, at once idealistic and hard-headed, open-minded but indomitable. When the challenge of improving Mexico's food production was put to him by Foundation President Raymond B. Fosdick, Harrar recognized it as an opportunity that would engage all his powers.

Six months later he was in Mexico, sounding out government officials, landowners, and farmers, surveying the agricultural situation, and sizing up the job he had undertaken. It was formidable. Mexico was an agrarian nation but suffered from food shortages. It was forced to invest large amounts of hard-won foreign exchange in importing basic foods which, some believed, could be produced within the country.

Irene Uribe was Research Assistant, The Rockefeller Foundation, New York, N.Y. Her chapter is based on an interview with J. George Harrar, President Emeritus of the foundation. Mrs. Uribe died early this year.

Today we know how this adventure turned out; it is one of the great success stories of 20th century agricultural development. Now called *The Green Revolution,* it embraces scores of countries around the globe. Harrar did not usher in the Green Revolution single-handed, but the conjunction of events in that early summer of 1942 was fateful. Asked to sum up the history and significance of his role in world agricultural development, Harrar recently agreed to an exercise in hindsight:

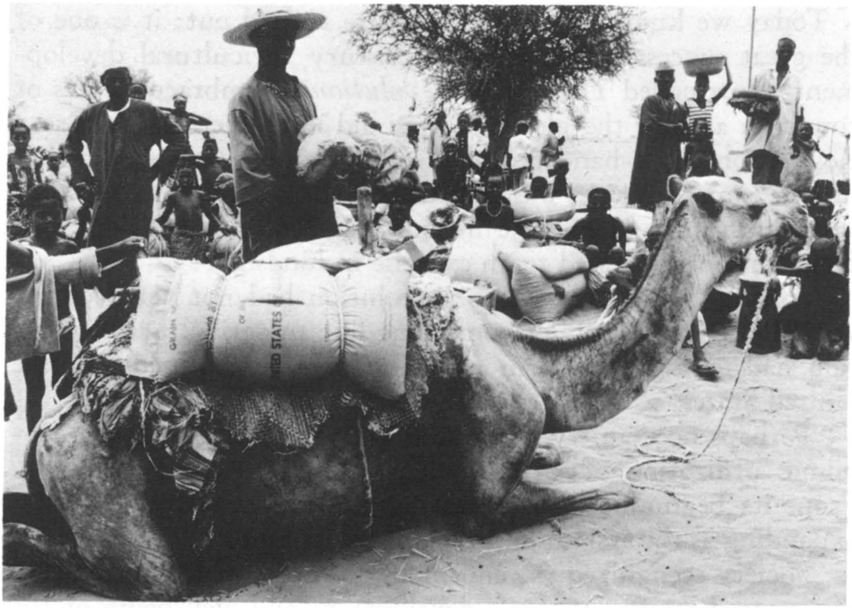
"Although the term Green Revolution had not yet been invented in the early 1940's, something like an agricultural revolution had certainly been in progress for several decades in the United States.

"Perhaps no country has placed greater emphasis on the economic utilization of its agricultural resources than our own. From its beginnings, American agriculture developed rapidly, expanding as the system improved in all its aspects.

"Society recognized the enormous resources which agriculture represented to the economic development and well-being of the Nation, and willingly and increasingly supported the physical aspects of farming. A multiple research establishment, the development of the great extension system in education, and the creation of a network of agricultural educational institutions complete with experiment stations for research have over the years contributed to our understanding of our agricultural resources, and their economic utilization.

"Our greatest strength has been the quality of the American farmer and his successful effort to improve the quantity and quality of agricultural commodities, both plant and animal, produced each year. Growing Federal and State understanding and participation in programs to promote national production, to preserve and protect arable land, forests, pasture and range land, and wildlife areas, have also been major factors.

"Especially important milestones were the Land Grant College Acts of 1862 and 1890, the establishment of the U.S. Department of Agriculture (USDA) in 1862, and the Hatch Act of 1887 which established the nationwide system of State Agricultural Experiment Stations. The result has been that food, fiber, and other agricultural needs have been met, with added economic benefits coming from international trade. In addition, it has also been possible, over the past two decades or more, to provide enormous quantities of foodstuffs on a concessional, humanitarian basis to alleviate crop failures resulting from natural disasters among the poor nations of the Third World."



U.S.-provided grain sorghum is distributed by camel in Africa's Sahel.

The U. S. experience with agricultural research, education, and extension was to be pivotal in the worldwide effort that grew out of the Mexican undertaking. Many of the problems Harrar encountered in Mexico were easy to diagnose, but others were totally unfamiliar. Harrar describes the situation.

Aftermath of Revolution

"In 1943 Mexico was still adjusting to the aftermath of its revolution. Large estates had been broken up, farm properties were generally modest in size, and the attempt to serve the needs of the landless peasants produced the 'ejidal' system in which many land parcels were microscopic, uneconomic subsistence units. However, a great nation of great people was determined to work its way out of the past, and its dramatic economic and social progress during the past 30 years is eloquent testimony to that determination and dedicated effort.

"Traditional varieties of corn and wheat were low yielding and coarse, soils impoverished, water all too often a scarce item, and widespread droughts frequent. Soil management practices were inadequate, fertilizers and other agricultural chemicals in short supply and costly. All of this was compounded by an inadequately designed and supported agricultural development

complex, a paucity of qualified agricultural scientists and other specialists, and a weak system of agricultural education."

Harrar's first move, following a personal reconnaissance, was to pick a small group of American scientists for a concerted attack on production problems. Making up the original team were two plant breeders, a soil scientist, a plant pathologist, an entomologist, and a botanist with a background in library science. (The multi-disciplinary, mission-oriented approach was to be a hallmark of the many research and production efforts that later grew out of the Mexican program.)

The team members selected by Harrar had been connected with U.S. land-grant colleges either as students or teachers, and were familiar with the important role of Agricultural Experiment Stations. Although they had never experienced life south of the border and had little idea of what lay ahead, the scientists who joined Harrar in Mexico had in common an adventurous spirit and a sense of dedication. They also recognized Harrar's exceptional gift for leadership. As Edwin J. Wellhausen put it in later years; "I wanted to work with a dynamic individual like George Harrar."

From the start, young Mexican scientists were brought into the program, for one long-term goal was to make Mexico self-sufficient in professional manpower as well as in its basic food crops.

Bridging the cultural gap was something both sides had to work at. Talking informally about the first of the program's famous field days, Harrar once remarked: "I have to admit that much of our work was pretty mysterious to the people. They didn't understand why we were there or whom we were working for. We kept bearing down on the fact that we were there for them . . . In fact, we let the Mexicans do most of the talking."

Barbecue Rapport

Better rapport was established at the barbecues that followed the demonstration-plot tours. Harrar's purpose, however, went deeper than getting the farmers' good will and cooperation.

"The Rockefeller Foundation fully recognized its guest role in Mexico, and was aware of the necessity and desirability of becoming a part of the local scene, to work in an atmosphere of mutual understanding and confidence towards important economic and humanitarian goals," he recalls.

"It was recognized that applied research was of fundamental

Displaying spike of triticale, a cross between wheat and rye.

importance, but that it would be necessary also to communicate continuously with farmers, scientists, government officials and others in the production system. From the beginning, training efforts were introduced into the program and support was provided to help develop an extension system as well as to reinforce national agricultural institutions.

"As the Mexican agricultural program developed over the years, positive results began to accrue. A pattern had emerged in which genetic improvement of crop varieties buttressed by soil management, weed, pest, and disease control, and the use of fertilizers began to pay off in substantially increased yields. By 1955 the gap in corn and wheat production had been closed. Mexico became self-sufficient for these important crops. A network of experiment stations had been established and an extension system organized."

Components of the research and extension apparatus in Mexico had many features in common with U. S. experiment stations and extension services. Fundamentally, they also reflected Mexico's needs and were adapted to Mexican conditions. For example, in crop improvement work the systems approach was emphasized, with each crop studied from several scientific viewpoints. As a result, once the high yielding pest-resistant varieties sought by breeders, agronomists, and farmers were available, they likewise had traits sought by nutritionists, economists, and consumers.

Success of the Mexican program, and of subsequent international efforts, was due in large part to the manner of proceeding Harrar adopted and stuck to even in the face of factional suspicion and ingenuous disbelief. He took the slow route of evolving technological and institutional patterns molded to local conditions, rather than trying to superimpose high-powered U. S. techniques on refractory Mexican realities.

Scientific colleagues and unsophisticated country people alike often expected to see an imported American miracle. Harrar's genius lay in helping them work a miracle of their own. However, one should not underestimate the importance of the American contribution.

"USDA and land grant college scientists and administrators were most sympathetic to the effort to assist Mexico and, over the years, have been helpful in manifold ways," Harrar recalls. "Advice and information were freely provided as were varieties of seeds for trial. Personal visits were exchanged, graduate students from Mexico were accepted for training, and USDA and experiment station scientists served as boards of agricultural advisors to the Foundation. Thus, the emergence of the Green Revolution was the consummation of a long-term cooperative effort in which many organizations and individuals had a role.

"As the program in Mexico began to demonstrate its potential for increased production, it attracted wide international attention. Colombia invited us to establish a similar program with agricultural research and development agencies in that country. The Foundation accepted the invitation in 1950 and over the years a highly successful cooperative effort has evolved, largely through the understanding and support of the Government of Colombia and the participation of large numbers of able and dedicated Colombian scientists, educators, administrators, and extension personnel.

"Results of the cooperative programs in Mexico and Colombia led to an invitation from Chile to establish a third program in that country. The invitation was accepted, and Foundation staff were posted to Chile to work together with Chilean colleagues in research and its application to developing the basic food production system of that nation.

"In the early 1950's, India sent observers to Mexico, and in 1955 requested Rockefeller Foundation collaboration in an effort to improve the yields of cereal crops there. Once again, the Foundation accepted the challenge and a far-flung program was developed emphasizing wheat, corn, and rice. Over the years, substantial gains in production have resulted.

"As the several national cooperative programs in Latin America and India progressed, they were able to reinforce each other in a variety of ways. When information, methods, and improved materials were developed in one of the several centers, they were made available to the others, and wherever else it seemed they

Above, farmers examine high-yielding wheat at India's Punjab Agricultural University, which is patterned after U.S. land grant colleges. Right, uprooting and transplanting rice in an India area irrigated under U.S.-financed program.

might be useful. Eventually, outreach projects were established in East and West Africa, Thailand, Indonesia, and Pakistan, as well as a number of countries in Central and South America. Each of the four original national programs was used as a training ground for scientists from other countries with the intention that on their return, they might develop local projects in food crop improvement."

Encircling the Globe

By the early 1960's, the legacy of the Mexican program had grown to enormous proportions. In 1952 Harrar had been named deputy director for agriculture of the Rockefeller Foundation and posted back to New York. From this vantage he guided the

expansion of overseas programs which now encircled the globe. He helped shape the patterns that were leading toward the grain production breakthrough that was to be known as the Green Revolution. He puts it this way:

"As country programs progressed, visible results began to accrue, especially in the form of substantially increased yields of the major cereal crops. These were recognized by farmers and others involved in the national food production system. The result was greater confidence on the part of growers, more support from governments, increased agricultural credit, and improved storage, transport, and marketing facilities provided. Perhaps most important of all was the growing evidence as to what could be accomplished in terms of greater food production through well-designed production systems.

"By the 1960's, the Mexican corn varieties were being grown, tested and improved wherever they were adaptable. Similarly, Mexican wheats were finding their way into important wheat-growing areas worldwide. These high-yielding varieties were making dramatic breakthroughs in yields in Latin America, Asia, and Africa.

"This was possible because of the genetic improvement of varieties and their use in production systems geared to the local environment. That could not have happened were it not for the growing number of well-trained nationals who were providing the critical mass necessary to assure sound and continuing progress towards established production goals. Furthermore, there was a gradual but effective development of informal international collaboration among organizations and institutions with similar objectives."

Harrar was a moving force in the formation of this international network. His appointment as president of the Rockefeller Foundation in 1961 extended the scope of his responsibilities to other areas, some of which, like agriculture, have direct bearing on the problem of feeding the world's growing populations. The Foundation had, among other interests, overseas programs aimed at strengthening universities in developing countries; faculties of science including agriculture, economics, and veterinary medicine later cooperated closely with the research institutes focusing on key crops and animal production.

The Foundation also had a program in population problems.

Harrar's involvement in the food-population crisis was thus intensified. As Foundation president, he was to play a decisive part in the extraordinary developments of the late 1960's and

early 1970's. These were the years that saw the creation of a unique global problem-solving system for agricultural development. Harrar recounts its genesis, starting with the establishment of IRRI, the International Rice Research Institute.

"The success of the cooperative program begun in Mexico in 1943 led to consideration of the wisdom of establishing a truly international research center dedicated to the improvement of a major food grain. Rice, as the world's major food grain, would be the ideal object of such a center, and the Republic of the Philippines would be an ideal location.

"The original concept was the product of mutual interest on the part of the Ford and Rockefeller Foundations whose representatives undertook to discuss the idea with the Government of the Philippines and certain local institutions. The President and other government officials expressed great interest and the desire to have the institute located in the Philippines; and afer a period of negotiation, a memorandum of agreement was signed.

"IRRI was constructed on land adjacent to the College of Agriculture of the University of the Philippines at Los Banos and was dedicated in February, 1962. From its establishment, IRRI worked in close collaboration with the University of the Philippines and other national organizations. As the research program unfolded, a training center, a library and documentation facilities were created to serve the rice-producing nations.

"Today, IRRI is working in intimate association with many national and international institutions worldwide. Improved rice varieties have been developed which are now grown and are contributing to substantially higher yields in many of the world's most important rice-growing countries.

"The rice research institute demonstrated the validity and efficiency of this sort of concentrated effort to improve cereal production internationally. Subsequently, three other institutes have been established by the Ford and Rockefeller Foundations in cooperation with selected host countries—Nigeria, Mexico, and Colombia. The International Institute of Tropical Agriculture in Nigeria is dedicated to improving agriculture in the humid tropics, as is the International Center of Tropical Agriculture in Colombia. The International Maize and Wheat Improvement Center in Mexico focuses its program on the improvement of corn and wheat production worldwide.

"Today these centers, in addition to support from the two original foundations, are assisted financially by other sources including the Agency for International Development, interna-

tional banks, the Kellogg Foundation, the United Nations Development Programme, and certain members of the Consultative Group on International Agricultural Research.

(The Consultative Group on International Agricultural Research has 29 members. They include governments of developed countries, United Nations agencies, regional development banks, private assistance agencies and foundations, and representatives of the major developing areas of the world.)

"Since 1971 several other institutes have come into being, largely through the initiative of members of the Consultative Group. The newer institutes include the International Potato Center in Peru, the International Crops Research Institute for the Semi-Arid Tropics in India, and two African centers: The International Laboratory for Research on Animal Diseases, in Kenya, concerns itself with trypanosomiasis and East Coast fever, two deadly cattle diseases. And the International Livestock Centre for Africa, in Ethiopia, works on animal husbandry and livestock production systems.

"The international centers are powerful tools for the production of new knowledge, methods, and materials, and their application for rapid progress in increasing food supplies worldwide. Their efforts are focused and concentrated and the results will, on a growing scale, be translated into more and better basic foods for millions of individuals presently economically and otherwise disadvantaged. Simultaneously, these centers are becoming important catalysts for the continuing development of national institutions and agricultural systems.

"The Green Revolution is pointing the way, not as an exclusive answer, but as a model and a powerful instrument which if applied effectively on an ever-growing scale, can contribute enormously to the goals we all seek."

Upon his retirement in 1972, Harrar was elected Life Fellow of the Rockefeller Foundation in recognition of his "unique contribution to the improvement of the human condition, in a world where such accomplishments are few." These words of Douglas Dillon, chairman of the Foundation's board of trustees, figured among the many tributes that poured in—some from distant parts of the world.

Former colleagues and associates praised his "foresighted and vigorous leadership," his "superb character, vision, innovative ideas, common sense, concentration, and perseverance." Statesmen of high rank in many lands acknowledged his contribution to their countries' development.

J. George Harrar

Mexico Is With You

From Mexico, the moving words, "Today Mexico is with you," spanned nearly 30 years of fruitful association.

During that time Harrar has received 12 honorary doctorates from universities throughout the world as well as numerous awards of merit and honorary memberships from scientific societies and universities at home and abroad. His many decorations from foreign governments include some of the highest awards that can be given to foreigners. To this impressive list of honors, an unofficial title has been added by acclamation: Architect of the Green Revolution.

"The phenomenon which has now become known as the Green Revolution is the product of a chain of events culminating, from a very small beginning, in dramatic benefits of world-wide significance," Harrar notes. "In capsule form, it is the application of a package of research, field experience, training, and communication, in a sustained effort to redress the balance between people and food where needs are greatest.

"The more developed countries cannot indefinitely satisfy deficit food production situations among other nations. Maximum benefits can only accrue when those agrarian nations, now in a chronic state of underproduction, move increasingly and effectively into a position of optimum utilization of national resources for the satisfaction of food and nutrition requirements for the population.

"All countries can and must work together to bring about greater self-sufficiency in food production world-wide through the establishment and development of sound agricultural planning and the support of those instrumentalities most critical to a productive agricultural industry."

Ecology . . . Never Having To Say You're Sorry

BY E. PAUL TAIGANIDES

In scientific jargon, ecology refers to the relationship and natural balance which exists among microorganisms, fish, birds, alligators, wildlife, bugs, plants, man and the natural environment. In other words, *Ecology means . . . Never Having to Say You're Sorry.*

After 200 years of industrial revolution and a full century of agricultural revolution, the current disposition of our society is one of growing concern with the problems of pollution and ecology. Although environmental pollution is a new anxiety for the majority of people in the United States, ecological studies were incorporated into the activities of State Agricultural Experiment Stations from the very beginning.

Man has had a definite effect on the ecology of the natural environment from the moment he appeared on earth.

However, human effects on the environment ranged from minimal at the time he lived as "hunter," to local influences when he domesticated animals and became a "herder," to regional ecological disruptions when man became a "farmer," and today they are global as man has become an "industrialist."

As a hunter, man's activities produced only temporary disruptions in the ecosystem of the small valleys where he hunted his prey. When man developed into a herder by domesticating animals, he caused agricultural disruptions of enough local significance to compete with natural changes in the ecosystem.

As a herder, man enjoyed a more steady source of food and more leisure time which he devoted to increasing his numbers and to advancing his technology. Population pressures and advanced technology caused the great mass movements from the

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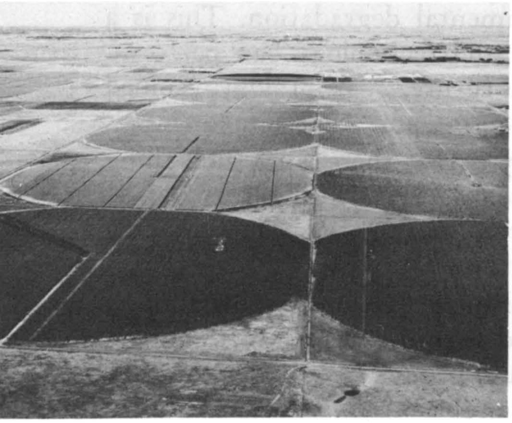
Above, mallard ducks and Canada geese on Tennessee pond. Right, fawns are part of whitetail deer herd maintained by New Hampshire researchers studying the ecology of wildlife, a general index of environmental quality.

Indo-European steppes into continental Europe and across the Atlantic to America.

For every man in the United States 100 years ago, there were 60 acres of fertile valleys, virgin forests, rolling prairies and lush grasslands. Soon oversized herds of cattle, sheep and horses made a waste of Nature's bounty.

The green prairies along with great tracts of marginal land were plowed up for a few years of crops, and were abandoned when their soil fertility was depleted. From the bare, abandoned land, from the overgrazed pastures, and from fields and forests



Left, green circles made from giant irrigation systems that pivot around a central point, Nebraska. Right, contour farming and stripcropping promote soil and water conservation in Wisconsin.

cultivated with no regard for ecology, there arose billowing clouds of dust bowls marking the first environmental crisis of America.

The Agricultural Experiment Station of the University of Missouri was the first to establish experimental plots to study factors affecting soil erosion by water and wind. Recognition of the ecological disruptive power of farming resulted in extensive soil and water conservation programs in the 1930's. In the meantime, the economic depression of that era hastened the pace of industrial development in the 1940's and 1950's.

Man as an industrialist is causing agricultural disruptions which have global significance. The application of large quantities of phosphorous, nitrogen, other plant nutrients and pest controlling chemicals is causing changes which go beyond the boundaries of regional ecosystems.

Penguins and Coprology

DDT sprayed with airplanes over cotton fields in Texas and over forests in Georgia may conceivably find its way to the fat tissues of penguins in the Antarctic.

It is true that the new industrial age has brought us economic affluence. However, the secondary effects of industrialization are pollution and ecological disruptions whose long-term effects we are unable to assess precisely.

Yet, human survival in the next century demands that we grow more food for more people, in less time, on decreasing

land areas, and with less environmental degradation. This is a Herculean task that only science and technology can perform. It calls for the new science of the future. . . Coprology (coined from the Greek words for waste, *copros*, and science, *logos*.)

The basic premise of Coprology is that there is no such thing as waste. Everything is a resource. *Wastes are resources out of place*. A resource which is neglected or for which an economic use has not been found becomes a waste.

Research at Agricultural Experiment Stations is now finding new ways of recycling wastes and turning them into resources. Livestock wastes, for example, could be used to produce methane gas in sufficient quantities to meet a substantial part of our annual natural gas consumption.

At an Ohio feedlot, manure is mixed with waste paper wood chips, is composted and used for horticultural crops. In California, manure from dairy corrals is bagged, given a German name like "Ringderdung," and shipped via the Panama Canal to the Rhine River vineyards.

Thanks to unprecedented advances in science and technology, we are beginning to see in agriculture the integration of most operations into a comprehensive input-output system of food and fiber production.

Even in animal production operations, we are beginning to see an assembly-line type of mass manufacture of eggs, milk and meats. Poultry and cattle can be raised in complete confinement with automatically regulated environment, automatic feeders, automatic waterers, and mechanized removal of eggs and milk.

Transition from pasture to confinement production has helped make it possible to meet the increasing demands for eggs, pork, and milk without an increase in the number of hens, pigs and dairy cows in the United States. Animal production units of 2 million hens, 200,000 beef cattle, 100,000 pigs, or 10,000 cows on one farm are now operational.

The average daily consumption of animal products in the United States is 1.7 pounds of meat, milk, and eggs. For every pound of animal product being consumed, 23 pounds of manure have to be disposed of.

Every day 3.4 million tons of animal manure are produced in the United States. If all this manure were to be discharged into our streams and lakes, the resulting water pollution would be

Left, Penn State researchers have found that plants can be grown on bituminous strip mine spoil banks by using treated municipal sewage effluent and sludge to provide nutrients and improve harsh site conditions. Right, readings show irrigation with effluent cools surface temperature and reduces toxicity of the extremely acid spoil.

equivalent to almost five times the pollution load of raw sewage of the total U.S. population.

However, agricultural wastes do not create pollution in proportion to their quantity. Agriculture wastes are responsible for less than 3 percent of annual fish kills due to water pollution.

There is a basic difference between wastes generated by agricultural food and fiber production and the auto, metal or chemicals industry. The former are natural byproducts which can be recycled in the natural cycle. On the other hand, car exhausts, metals or plastics undergo little degradation and dispersion by natural processes. Nature does not manufacture and, therefore, does not have a niche for aluminum cans, plastics, stainless steel, or wastes from mining and the manufacturing of long-lasting products.

Replanting and reclaiming land scarred by coal and metal mining has been shown to be technologically possible. As our demand for energy and metals grows, so will our need to return our mines into productive lands.

Refuse Into Steam

Urban refuse is being turned into steam energy, feed for animals, and compost for abandoned strip mine areas. City sewage when utilized on agricultural land enhances the productivity of

the soil. Extensive sandy soils around several large cities in the United States are being developed into farming areas.

Manure can be a natural fertilizer and soil conditioner without creating gross environmental pollution. Manures produced in a year's time contain about 12 million tons of nitrogen and 3 million tons of phosphates and potash.

Applied on America's 400 million acres of cropland, manure meets only a small percent of our fertilizer needs, however. Consequently it is essential that we use commercial fertilizers besides animal manures.

The notion that we can grow without chemicals the necessary food and fiber for the 3-soon-to-be-6 billion people on the Earth is absurd. About one-third of our protein nitrogen intake in this country originated from man-made and applied nitrogen. This figure will continue to increase.

What will cease to increase is the excessive use of nitrates, phosphates, pesticides, and other chemicals. Chemicals that are "out of place" are pollutants. Chemicals used at the wrong time, for the wrong plant or pest, at the wrong rate, and so on, become pollutants.

Pointing to the great contributions of agricultural chemicals to the survival and well-being of the human race does not give us the license to use these chemicals indiscriminately. Research is already beginning to perfect equipment which will apply chemicals at the right dose, at the right time, to the intended target.

Very little can be disposed of in earth's biosphere without affecting ecology. Disposal, therefore, must be done in such a way and at such a rate that Nature will be able to assimilate it. Man must help Nature assimilate his wastes, or we will be sorry.

By 1977, the beginning of the third century of the American Republic, and the beginning of the second century of research by State Agricultural Experiment Stations, no pollutants will be allowed to be discharged in any of the water bodies of the United States from industrial point sources.

By 1984 all sources of pollution, public and industrial, must cease discharge of all pollutants. Strict laws will be enforced on car exhaust emissions and power plants by 1977.

These laws will strain our economic sector, but in the long run an ecologically feasible industrial age will emerge.

Better Mushrooms, Hops, Tabasco, and Even Mink

By Glen W. Goss

Mushrooms, once an infrequent delicacy in our diet, are now enjoyed regularly. Consumption in this country has tripled since World War II—from a half pound to a pound-and-a-half per person each year.

Research at State Agricultural Experiment Stations plays a major role in perfecting the production, processing, and marketing of commodities of local importance. The mushroom story is one of many examples of significant research efforts in helping agriculture provide us with some of our more unusual products.

Pennsylvania produces nearly 60 percent of the U.S. mushroom crop. Thus, it is only natural that Pennsylvania State University scientists have been working with mushroom growers for a half century.

In 1925, C. A. Thomas started 35 years of dedication as an entomologist developing pest control programs. The first research facility, a mushroom test house, was completed in 1928 with funding support from the Mushroom Growers Cooperative Association. Joint efforts in the industry and cooperation with scientists in the U. S. Department of Agriculture (USDA) and at other land-grant universities followed as Penn State became a focal point of mushroom research and education.

Today, mushroom growers in Pennsylvania employ close to 10,000 people and the cash value of their product in 1974 was $63.8 million. As in any industry, mushroom growers have faced a series of crises.

In the 1960's, cheap-labor imports from Formosa brought concentrated efforts in sharpening production methods and in developing markets.

Glen W. Goss is Director of Agricultural Communications for the College of Agriculture, The Pennsylvania State University, University Park.

In the 1970's a scare, brought about by a precautionary Food and Drug Administration recall, was a temporary threat to the canned mushroom market. Research came to the rescue in responding to calls for aid from the individual mushroom growers and American Mushroom Institute.

New and safer mushroom products now are on the market in competition with foreign imports. Consumers are offered a wide variety of mushroom taste treats as growers meet the challenge.

Development of grain spawn free from pests and disease by James W. Sinden in the early 1930's brought significant changes to the industry. Stressing mushroom development in relation to nutrition beds, Sinden was advised not to work on spawn "as all problems in the field were settled, the process is known in its entirety, and no further improvement could be made." But, seeking a more dependable medium to use in his tests, he went ahead.

"One of the first new mediums tested was grain, specifically wheat, which was placed in flasks with a small amount of water and sterilized. On introduction of the mushroom mycelium (small hair-like roots), I found that it grew very vigorously in a manner different than anything I had previously seen."

Further tests were convincing, and several patents were obtained on the Sinden Grain Spawn Method in 1932 and 1933. Since then, the university's spawn laboratory has been responsible for 60 to 70 percent of the basic culture in the Nation and has been a significant factor in strain selection.

Average commercial yield in pounds per square foot of bed planted has increased from 1.5 in the late 1940's to 2.65 in the early 1970's.

This increased efficiency can be largely attributed to Penn State's mushroom research and educational programs in forced air ventilation systems, low temperature Phase II composting of the growing medium, vegetable oil nutrient supplementation of the compost, machine spawning (seeding) of the mushroom beds, a pest-management program based on a biological foundation, and development of a new fungicide for control of certain diseases of mushrooms. Another research project has shown that loss due to processing shrinkage can be reduced at least 10 percent.

A Mushroom Test-Demonstration Facility was developed and put into operation at Penn State in 1971. A flow-type design saved both time and labor. An automatic materials handling system, whose components are integrated by environmental control equipment, allows introduction of composting materials as a

growth base at one end and removal of mushrooms and spent compost at the other end.

This labor-saving approach results in 6.5 crops a year instead of 2.5 crops. An annual harvest of 22.7 pounds per square foot compares with a traditional 6.5 pound yield.

This model is showing growers how they can adjust their methods to be more competitive in world markets and provide you with a delightful array of mushroom products that fit in your food budget.

That Good Beer

Hopping is something little girls do when they play hopscotch. But mention the word to a brewmaster, and his mind will instinctively run to another kind of hopping—the process that gives his beverage the distinctive flavor and aroma that makes beer taste like beer.

Washington's Yakima and Moxee valleys provide more than 65 percent of the nation's hops. Some 150 farmers receive about $27 million a year for the crop. The remainder are grown in Oregon, Idaho, and California.

Left unattended, hops flourish like a weed. But, producing the high quality demanded by brewmasters is a difficult proposition. Historically, hop culture was a family skill passed down from father to son. It was under this system that Jacob R. Meeker planted Washington's first commercial hops in 1866 in the Puyallup Valley not far from Seattle.

There the industry flourished for nearly two decades. However, the relatively wet climate unfortunately provided excellent conditions for downy mildew. This fungus drove hop production from Western to Eastern Washington. It also reduced Oregon hop production from a peak of 35,000 acres to only 5,300 acres today.

Diseases, insects and mites, and quality problems caused growers to turn to research scientists at Washington State University's Irrigated Agriculture Research and Extension Center near Prosser. Achievements are many and valuable, but three stand out: control of diseases and other pests through chemical and cultural practices, release of new hop varieties, and development of virus-free planting stocks of new varieties.

Financial help came when the Washington State Hop Commission was organized in 1964. Contributing $11,000 a year

until 1973, the growers voted to increase their assessment for research by 50 percent—a measure of their esteem for the work of the agricultural scientists. Another significant source of industry finance is the $30,000 a year coming from the United States Brewers Association.

These funds greatly increase the effectiveness of research at Prosser supported by State and Federal funds.

The search for better hops began in earnest in Washington in 1956 when Calvin B. Skotland, a WSU plant pathologist, surveyed Yakima Valley hop yards where varieties were suffering from virus diseases and nutritional deficiencies. He selected 41 vines for evaluation. After nine years of work, Skotland released three lines of cluster-type hop roots with improved quality and disease resistance. They quickly became the predominant varieties in Washington.

At the same time Stanley N. Brooks, then a USDA Agricultural Research Service agronomist stationed at Oregon State University in Corvallis, developed a cross with superior characteristics. After 16 years of research and development in Washington and Oregon, a new variety called Cascade was released in 1972. It opened a new horizon for Washington's hop industry.

Cascade, a European-type hop, is preferred by some breweries that rely heavily on imports. About 14 million pounds of hops are imported every year, but Cascade is expected to cut into that market and keep more American dollars at home.

When first released, Cascade was not certified virus-free. But, Skotland had already started research on that problem in 1965. Borrowing a technique developed by WSU tree fruit researchers, Skotland began growing hops in heat chambers. It takes time for viruses to spread to new tissue. So by speeding growth in heat chambers, scientists can produce virus-free tissues which are clipped off and propagated under carefully controlled circumstances which keep the plants disease-free.

In 1972, Skotland released 21,000 virus-free cuttings of Cascade hops from which four growers are producing certified virus-free stock for sale to the industry.

A second new variety, Comet, has been released as a high brewing value hop that should be especially useful for extracting and export markets.

Comet is the result of a cross made by Charles E. Zimmerman, an Agricultural Research Service agronomist then stationed at Oregon State University. Jointly released by ARS,

WSU, and OSU, it is more tolerant to downy mildew crown infection than the cluster varieties presently grown, and is tolerant to ringspot virus found in hops in the Pacific Northwest.

These are only a few highlights of what scientists are doing to help ensure the nation's supply of flavoring for beer, and to help make the Pacific Northwest's economy a vital one.

Tabasco Threatened

Often we are unaware that, because of agricultural pests, we might lose something we enjoy. Spread of TEV (Tabasco etch virus) in the Southern United States in the 1950's threatened survival of tabasco sauce—the tangy, taste-tempting treat. This wilt disease, spread by aphids, was defeated by a 20-year breeding program that developed a resistant tabasco pepper variety.

Louisana experts in the heart of the pepper-growing country where tabasco sauce is produced feared in 1959 that if the spread of TEV could not be halted, the state would have to stop growing the pepper. At this time, W. H. Greenleaf had begun to breed TEV-resistant tabasco peppers in the Agricultural Experiment Station at Auburn, Ala.

Greenleaf Tabasco, named for the pathologist and plant breeder who developed it, is not only TEV resistant—it boasts several other desirable characteristics. The new variety is providing growers with resistance to ripe rot; it produces a more concentrated fruit set, thus increasing harvest efficiency; and it has a darker yellow immature fruit and a darker red mature fruit, as well as stronger pungency.

Two Indian pepper varieties from Peru provided the resistance factor in the painstaking breeding program. Four backcrosses to the original tabasco variety were made. The alternating self generations were screened for etch resistance after each backcross. Also, at the third backcross level, breeding techniques called interline crosses concentrated the genes for other desirable characteristics.

Your opportunity to enjoy tabasco sauce thus was preserved by research. As frequently happens, scientists made no spectacular overnight discovery. Clues indicating they were on the right track provided the encouragement for further improvements so that we can still have the fiery hot pepper seeds to make the vinegar extract that, through processing, becomes tabasco sauce.

Minks and Finks

Michigan State University's fur-animal research project got underway in 1948 with a grant and a gift of mink from the Michigan Fur Breeders Association. In addition many other commercial companies are active supporters of the project (private industry and fur-farming organizations at one time were matching the university's dollar input two to one).

Administered by the MSU poultry science department, the project has involved scientists from zoology, physiology, and veterinary pathology. More than 43 papers were published in the past decade. The present work load of the project includes a number of studies designed to provide answers to everyday problems in the industry.

A marked increase in mortality of newborn mink developed in the mid-1960's, when coho salmon taken from the tributaries of Lake Michigan during the spawning run were fed to mink. MSU workers found substantial levels of polychlorinated biphenyls in the salmon, and proved that these chemicals were causing deaths in the young mink.

Recent studies have sought a practical procedure for artificial insemination of mink. A procedure for collecting semen by electro-ejaculation was developed. In subsequent experiments, techniques for handling and extenders for diluting, holding, and storing mink semen were tested and evaluated.

Many shock-type losses associated with anemia have occurred on mink ranches. Studies at Michigan State University have been established to obtain a clear understanding of the ailment, discover the type of anemia involved, determine the heritability of the condition, identify the factor responsible for the problem, and find a remedy or treatment for the disorder.

In addition, research is being conducted on mercury poisoning from contaminated fish and cereals, blood and cardiovascular parameters, and the influence of vitamin E on reproduction in mink.

Research frequently leads to interesting sidelights, even though in some cases the results are negative.

Because of their vicious nature, mink must be raised in individual cages. Scientists have tried tranquilizers and other methods to calm them, hoping to be able to raise mink in colonies. They have had little success.

Using artificial breeding techniques developed at Michigan State University, Richard Aulerich thought it might be possible

to breed more calmness into mink by selecting for this trait or by crossbreeding with closely related calmer animals.

The ferret was one possibility. This cross was tried. In discussing the project, Aulerich said, "If the offspring has the mink's fine fur and the ferret's disposition we'll call it a 'merret.' If it has the mink's disposition and the ferret's coat, we'll call it a 'fink'!"

Attempted crosses to date have come up with nothing. Aulerich is quite philosophical and says, "We knew that in such a cross we could get the ideal we were looking for, or we could get a new species of animal, or we could get nothing. So we weren't too surprised when we got nothing."

Peanuts and Pyrazines

Work with some specialized commodities, such as peanuts, can have far-reaching effects. At the Oklahoma Experiment Station a new era of understanding food flavors was ushered in when biochemists, while seeking to improve the taste and keeping quality of roasted Spanish peanuts, "rediscovered" the important role of nitrogenous organic compounds called pyrazines.

The role of pyrazines had first been discovered by Staudinger and Reichstein in 1927. The knowledge went almost unnoticed until 1963, when new research was published by M. E. Mason, Oklahoma biochemist. With that publication, "the little hole in the dike" became the flood.

At first only five pyrazines were identified. Currently more than 100 are known in practically every cooked food consumed by humans.

As a result, your taste buds frequently get a new taste because the manufacture and use of pyrazines in flavoring has revolutionized the food industry with flavorings that were not possible ten years ago.

Oklahoma scientists have developed an improved technique for rapid amino acid analysis of peanut varieties. This technique will assist scientists in their around-the-world search for peanuts high in protein and vital amino acids.

Kicking the Maple Bucket

Indians used the "sweet water" that flows from a wound in the sugar maple each spring as a source of sugar. From colonial times through the end of the 19th Century, maple sugar was an important staple in rural New England. After white sugar became cheaper, maple sugar and sirup continued to be widely used as

foods. Today, maple flavor also is found in many food products.

Production in the nine major maple states remains at about one million gallons a year. Vermont usually leads the nation with more than a third of the production.

Since Vermont is almost synonomous with maple, it is only natural that Vermont's Agricultural Experiment Station has been a leader in maple research.

Techniques of harvesting and processing maple sap into sirup changed little until after World War II. Research at the university's Proctor Maple Research Farm demonstrated advantages of continuous flow from tree to gathering tank. Plastic tubing made central gathering possible and eliminated buckets on trees that had to be gathered regularly, frequently through hip-deep snow.

Studies of the basic chemistry and physiology of the sugar maple (*Acer saccharum*) started in Vermont nearly 50 years ago. Cooperative work is conducted with the new U. S. Forest Service facility in Burlington, Vt., USDA's Agricultural Research Service Laboratory near Philadelphia, Pa., and with other State Experiment Stations.

Techniques have been developed to determine sugar content and flow of sap to identify superior trees in a natural stand. Vacuum pumping has increased yields from tubing systems, reducing manpower requirements.

New evaporator designs utilize modern fuels to reduce the time needed to boil away excess water while producing high quality sirup. Evaporator studies are being conducted in conjunction with the Forest Service, a USDA agency.

Modern methods also cause problems. With larger producers using oil to fire their evaporators, the energy crisis brings a new threat. Now research is focused on an automatic wood residue fuel system, intended to help maintain production while lowering costs.

Farmers practicing the art of maple sugarmaking were helped in their battle against long, hard hours and costs as the industry emerged from a "cottage handicraft" business to large-scale, self-sufficient units. Frequently, producers are now vertically integrated from production through processing and marketing to make their tasty product available at reasonable cost.

So if your mouth waters for the tasty sirup of maple on your pancakes and other treats, rest assured that maple sugarmakers and scientists are working together to keep those maple products flowing.

Systematizing the Tomato, Or More Punch for Pizza

BY O. A. LORENZ AND MELVIN N. GAGNON

Mention the word "tomatoes" and the mind flashes pleasing red images of catsup and hamburgers . . . pizza . . . spaghetti . . . tomato juice.

We can almost taste these tangy visions because the canned tomato and its many versatile products have become so firmly adopted—in fact, are expected—in the American diet. The per capita consumption of processed tomato products is equivalent to 50 pounds of the fresh fruit that goes into the can or bottle as paste, sauce, slices, wedges, stewed or whole tomatoes, or as one of the many special sauces or condiments we use constantly to spark our meals.

How was the canned tomato able to achieve such a prominent place in America's eating? By a systems approach matching crop varieties to cultural practices that enhance their production, and to machines that harvest them quickly and efficiently. Each of these components must function perfectly if high yields and quality are to result. If any one component fails, then the whole system fails.

The systems approach has put the canning tomato industry, now centered in California, through an agricultural revolution. It has seen the substitution of capital—largely investment in machines—for a declining hand-labor force. There has been a complete revamping of the production process. We have new, higher-yielding plant varieties and ways to grow them. We have better harvest, handling, and processing methods that get more tomatoes out of the field and into the can.

O. A. Lorenz is Chairman of the Department of Vegetable Crops, University of California, Davis. Melvin N. Gagnon is Educational Communicator—Plant Sciences, UC Division of Agricultural Sciences.

Half Million Tons a Week

Actually, there are many interlocking systems, from planting the seed to getting the final product on the user's plate. To see why this is so, consider that during the season peak in California more than a half-million tons of raw fruit per week are coming off the fields.

Week by week, this goes on for four months. It starts early in the warm southern desert near the Mexican border. Production advances gradually northward—more than 600 miles over the season.

Orderly movement demands close on-the-farm and between-farms scheduling of planting, fertilization, irrigation, pest control, harvesting, and hauling. Within and between the regions the whole industry must plant and watch and guide this flow through constantly changing seasonal conditions.

The river of tomatoes cannot be allowed to back up or spill over once it's moving.

Before such a tremendous, coordinated system was brought into play the California industry was concerned about a shift elsewhere, or at least a serious decline in the state's production. Production costs were outrunning raw tonnage prices to farmers. The impending shutdown of foreign labor imports gave growers visions of their crops rotting in unpicked, unpaid for, fields.

The "system" reversed those threats. By 1974 production had climbed by 50 percent to a national supply of seven million tons of raw fruit. California's contribution in 1974 was six million tons grown on 250,000 acres and production is still growing rapidly.

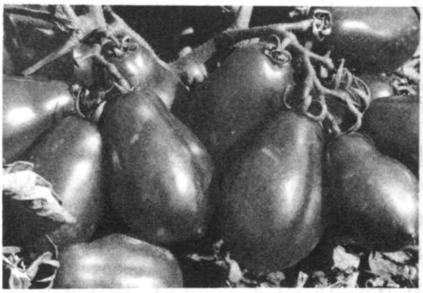
Ironically, this country no longer exports tomato products. Instead, imports help fill the demand created by a taste-hungry public.

The changes in California have been good for more than just the consumer's appetite:

• Through the trial years of costly conversion from hand labor to machine harvest, retail prices were stable or rose only a few cents per can

• The lack of foreign labor as a domestic tomato production problem has dissolved; the sorting of fruit on mechanical harvesters is met predominantly by local rather than foreign or migrant American workers. Housewives and high school students now make up a large part of this seasonal force

Yes, these are dramatic changes easier to look back on than to



Top left, stoop labor in picking tomatoes was costly and time consuming. Top right, mechanical harvesting cuts labor costs and increases production and quality of tomatoes for canning. As harvester moves along, conveyor belt drops tomatoes into giant truck trailer. Above left, canning tomato production has increased due to new varieties, such as this Nova variety developed in New York, that resist major tomato diseases. Above right, USDA researcher at Washington State is seeking new varieties resistant to diseases of Western deserts.

have predicted. In fact, the far-sighted scientists and engineers in California were branded as "crazy" when they started talking of picking tomatoes by machine, and began doing something about it. They doggedly stuck to their early convictions that change would come. It did; it surely did!

In the 1940's G. C. (Jack) Hanna, an experiment station plant breeder in the Department of Vegetable Crops at the University of California's Davis campus, began a special series of tomato plant crosses. The developing trend already was toward smaller plants with the Pearson variety, released shortly before by Oscar Pearson of Davis.

Up until then, most standard varieties, the so-called "nondeterminant" types, would grow and set fruit continuously over the season. They had to be picked repeatedly to take full advantage of their fruiting capacity. Each picking, of course, added greatly to the production cost.

Hanna's goal with concentrated fruit set was uniform ripening so all the fruits could be taken in one picking. The solution went beyond the hand-labor problem; more importantly, it

showed how today's "once over" mechanical harvesters could become practical.

Ideal Tomato Shapes Up

As his ideal tomato began to shape up, Hanna joined with Coby Lorenzen of the UCD Agricultural Engineering Department. Both recognized that if a mechanical harvest system was to work, the machine and the plant had to be compatible. A wide range of individuals—researchers, farmers and industry members—began to contribute.

Still, critics called the early efforts a waste of time and tax-paid research dollars. Hand labor for harvesting tomatoes was plentiful through the Bracero program with Mexico, and nobody needed a picking machine.

By 1962, Hanna and Lorenzen had both a variety and a machine and two percent of the California acreage used them. In four years three-fourths of the crop was machine picked, and by 1970 the last few hand-picked field lugs had disappeared.

The rapid and wide expansion of canning tomato production, both seasonally and over a larger area in California, is traceable directly to that 1962 variety of Hanna's.

This first practical variety, VF145 (V denotes resistance to verticillium wilt, and F to fusarium wilt plant diseases that destroy vines or reduce production), had the outstanding ability to set fruits over a wide temperature range.

Fruit set not only was concentrated so that most tomatoes came ripe within a few days of each other, but the early ones hung on the vine without spoiling. The thicker walls of the smaller fruits withstood the rigors of mechanical picking, especially in those rough first years.

Hanna immediately came out with a second release, VF13L. Its small, pear-shaped fruits had skin less subject to cracking, and gave canners excellent peeling and high product viscosity—qualities especially important in processing.

All these changes have meant more to California than to other States; West Coast production climbed from 65 percent of the national production in the early 60's, to 82 percent in the 1973 harvest. Midwestern states of Ohio, Indiana, Michigan and Illinois have maintained about the same production, just over 10 percent, but growers in Delaware, New York, New Jersey, Maryland, Pennsylvania and Virginia have given up ground to California.

Midwestern States, and the Eastern States especially, have not been able to take to the machine-based system. They still lean heavily on hand picking. Weather is the problem. California's new varieties are not suited to their frequent summer rains, and plants keep growing and fruiting. Also, rain-muddied fields stall the heavy harvesting equipment.

The harvester has evolved somewhat from Lorenzen's first-generation design, but still has proved much simpler than most early skeptics envisioned.

The plants are cut at the soil surface, raised onto the machine as it moves down the row, and the fruits shaken onto a sorter belt. Ripe fruit is conveyed to a trailer moving along with the harvester, and hauled to inspection and processing facilities.

Each harvester carries from 10 to 20 persons to sort out green, overripe, or other undesirable fruits. These, along with the vines, drop back onto the row and later are worked into the soil. Field disposal of discarded fruit helps reduce sewage problems in communities where canneries are located.

Speed Proves a Problem

At first, Lorenzen's team of engineers found their machine picked faster than it could unload the ripe fruit. The usual 50-pound field lugs filled up so quickly they couldn't be moved and stacked quickly enough.

The engineers switched to large bins. Surprisingly, the highly perishable tomato showed it could withstand the pressure of being piled in large amounts, and 1,000-pound capacity bins became the standard.

However, with machines now able to pick 100 tons of tomatoes per day, and cover up to 25 acres of crop per week, even the bins proved too small. Most of the industry, therefore, has shifted again, this time to bulk trailers that each hold an amazing 12 tons of fruit.

Early machine harvest cost was only slightly less than hand harvest. As the bugs were worked out, harvesting costs dropped to today's average of about $12 per ton. It is even lower in high-yield fields.

With present efficiencies, costs now are estimated at from 50 to 75 percent of what hand harvest would cost in California. Unfortunately, no data base is available for comparison because there has been no hand-picking for several years.

But what is known is this: an exceptional worker could hand-pick up to two tons of tomatoes per day, putting them into lug boxes dragged along the row and carried to roadside when full. The average pick, however, was closer to one ton per day. On that basis the 1973 California production of five million tons would have called for five million man-days of hand labor, a workforce input no longer available.

Not only has the number of workers engaged in harvest operations dropped, from a California peak of around 45,000, to 15,000 to 18,000 now, but the number of commercial growers in the state has gone from several thousand down to 600.

The systems approach does require larger acreages to use machinery efficiently. The average processing tomato operation now is at least 300 acres. The tremendous investment required limits grower diversification into other crops, so today's fewer growers are essentially specialized.

California's crop is picked by a fleet of around 1,400 machines, each now costing over $50,000. The original University of California licensed design is still prominent. Three companies currently handle the manufacturing needs. In mechanization's first years, adaptations and valuable changes came from countless, small equipment shops and farmer-innovators.

Research on cultural practices has proved as important as the varieties and the machine. It has provided a timing system that begins harvest when about 70 percent of the fruit in the field is ripe. Within a few days 90 percent will be ready, and before the field is done many operators will be pulling off 95 percent of the vines' capacity.

18 Tons an Acre to 25

The obvious dividend from cultural research has been the tremendous yield increase over the past 10 years, still using the same basic varieties: The yield has shot from 18 tons per acre to 25 tons state average.

Initial studies quickly demonstrated why precise management is important at all stages of tomato plant culture. Uniform fruit maturity demands uniform plant growth. This requires a good seedbed, free of large clods, for good seedling emergence and so preplant herbicides will keep competing weeds in check.

Uniform beds are essential for effective tillage, for the use of mechanical thinners, and for applying or incorporating pesticides and fertilizers.

Plant schedules that provide orderly harvest have been noted. But it also was found that direct-seeding had to replace transplanting. Plant populations went from several thousand per acre to an optimal 30,000 to 50,000 to help build yield. While this suggests that 100,000 plants might produce even more, such is not the case. Extensive trials proved that such a volume of plants is not worth the added cost.

Precision fertilization is most important. Nutrients must be plentiful and available to young seedlings. Researchers found that starter solutions placed under the seed get plants off and running together. Placement and timing of later applications can also be critical, and soil type must be considered.

Plants must be adequately, but not excessively, supplied with nutrients. It is important that they use up the nitrogen supply and stop growing, helping the crop mature uniformly for once-over harvest.

In contrast, over-fertilization with nitrogen produces excess foliage that slows harvest, and scatters and delays fruit-set and ripening. It also contributes unnecessarily to buildup of chemicals in the environment.

Irrigation, too, came under a system. The new canning tomato varieties are faster growing and with their loads of fruit all maturing at virtually the same time, water management can be critical. However, irrigations are discontinued from 10 days to as long as 40 days before harvest to get the plant to "shut down" for picking. Withholding water just before harvest also substantially improves the solids content of the fruit.

Weed and other pest control must fit into the production schedule. Weedy fields rob the tomato plants of vital growth and make harvesting difficult. Insects and diseases can kill or stunt growth, and affect both yield and quality. Since pests and their control are highly complex, researchers have had to determine the most suitable materials, their timings, and the methods of application.

Virtually all chemical applications follow university-developed guidelines for productivity, as well as safety to the crop, environment, and workers. State and Federal laws, enforced by county agricultural commissioners, guard against chemical abuses.

Since growers are responsible for violation of chemical residue tolerances—if any—on their products, the most direct safeguard is an economic one. The canner will reject tomatoes suspected or proved to carry illegal residues.

The best way to eliminate the added costs of pesticides, and the questions of safety, is to eliminate the need for external chemical control. Therefore, the long term research goal continues to be development of plants naturally resistant to insects and diseases. Complete resistance, however, is a long way off.

Uniform Ripening

Research also has continued in each of the other phases of production that we have outlined in this tomato story. The newest and perhaps most exciting innovation is the use of chemicals to promote uniform fruit ripening. Ethrel (chlorethylophosphonic acid), an ethylene-yielding compound, is applied to the plants at concentrations of 500 to 1,000 parts per million.

The ethylene, a natural plant hormone, hastens the ripening of mature-green fruits but does not affect the immature green or those already showing red. The net effect is more ripening uniformity and more useable fruit from the plant for the one-pick process.

Also on the horizon are new varieties that will have better flavor and color, higher solids, increased vitamin C content, higher viscosity, and firmness to withstand pressures in bulk loads.

Plant breeders agree there has been sacrifice in flavor and texture to get the systems approach functioning. They accept responsibility and are, in fact, taking leadership for improving the nutritional quality of tomatoes. This is an especially promising field, because in these experimental years they have discovered more of the biochemical components involved and the genetic pathways for altering them for man's benefit.

Again, the varietal improvements will almost certainly require changes in many of the "new" cultural operations. Such factors as row spacings, plant populations, weed control, fertilization, and irrigation will change as the new varieties are introduced and as innovative research demonstrates the changes which should be made.

Machines presently under development will do a better job of harvesting the fruits and will have the capacity for more rapid harvest. Some of the newest machines have twice the capacity as those in use five years ago.

Yes, continued research to improve and integrate the components of the production system will play an important part in the still-unlimited development of this dynamic industry.

The People—Food Race, And How to Win It

By Joseph J. Marks, H. R. Fortmann, J. B. Kendrick, and S. H. Wittwer

Here we go into the future. It could be a pretty rough trip. World population keeps growing. Energy and other resources are limited. Some accommodation for this situation must be found.

We could keep going the way we are. That means we find some miracle that gives us boundless new resources . . . or that we just continue using up our resources in one final orgy of 20th century materialism.

Or we can take another route. Change life styles—at least enough to buy time for agricultural scientists to learn how to squeeze more out of every acre.

As agricultural experts, we are optimistic about food production. We think we can "feed the world of tomorrow" . . . by reshaping plants to make better use of photosynthesis, by harvesting the oceans, by building super plants and animals, by "inventing" food in ways that haven't even been thought of yet.

That may not be enough, unless we solve some "people problems" too.

There is increasing evidence that we must have population control. If population projections for the future hold true (the United Nations has predicted there will be 12.3 billion human beings on this planet before the numbers level off in the next century), we must either control population or create a Shortage Society.

Even if it were possible to feed, clothe and house all these

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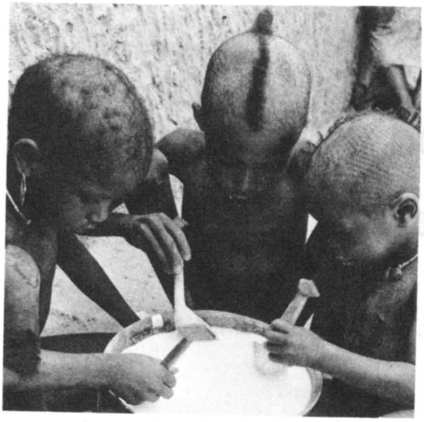



Right, Rutgers specialists brought trickle irrigation and mulching to this Nigerian village, in research on extending limited water resources. Left, youngsters in Nigerian refugee camp dip into daily bowl of high-protein porridge. They also are furnished with milk daily, in U.S.-assisted program.

projected billions, we could expect a whale of a lot of other problems with people living under such crowded conditions.

Those of us involved in science have, heretofore, contributed mainly to the technical innovations that relate to such "people problems." We think it's time for scientists to move out from behind their test tubes to give guidance to world leaders. We expect scientists to become more involved in the social issues of the day and apply what reasoned knowledge they can to help solve them.

What are research priorities for the future? It's easy to conclude that we need more of everything: more research on the environment, plants and animals, the elements, etc. Equally important is *how* we get the job done.

You've heard the cliches: "teamwork" . . . "pulling together" . . . "interdisciplinary research" . . .

Cliche or not, that's the way it's got to be if we are going to be successful. Agricultural problems no longer are the exclusive property of agricultural scientists. Right now, around the world, we're designing more coordinated attacks on agricultural problems that involve the diverse talents and resources of many organizations and institutions.

More important, however, is the *feeling* that we must work together for the whole human race.

That love . . . that caring for all those who reside on this

humble planet . . . is the most important influence on research priorities.

Our research programs must know no borders, geographical or otherwise. We must avoid being locked into old formulas, organizational patterns and concepts. We must build a *broader basic research base.*

If agriculture is to do all this and feed those projected billions of people, our claim on energy needs must come ahead of air-conditioning, personal transportation, and the like. In other words, it calls for financial and moral support for agricultural research as an investment in developing and conserving energy.

As we keep building on that international resource we call food production, we must keep in mind that a research effort must be based on *environmental management.*

Making Allies of Nature

The idea is to make allies of the components of nature and think in terms of getting the greatest return in food production with the least expenditure of energy. It means we don't spend the money and resources required to wipe out every disease or pest that comes along. We learn to *manage* pests with the least cost to ourselves and our invironment.

Population control . . . a broader research base . . . environmental management . . . teamwork. Those are the requirements for the future.

We have only so much talent, skill and money. How do we use them most effectively? We asked this question of the Agricultural Experiment Station directors and land grant universities across the country.

Here are some of their priorities:

Monitor the environment. That means knowing our environment from the inside of molecules to outer space. The information-gathering capabilities of electron microscopes and orbiting satellites provide warnings of disease and insect outbreaks and help us manage our environment.

Watch weather and climate. Scientists estimate that 60 to 80 percent of the variability in crop production, whether boom or bust, can be explained by weather variability. The message: Don't take climate for granted; help plants and animals (including humans) adapt to it.

Advanced weather forecasting and weather modification, plus

computerized farm management, will help farmers take full advantage of rainfall, sunshine and temperature changes.

Build gene "banks." The idea is to avoid genetic vulnerability. Complete characterization of genetic lines stored in computer banks will give us insurance that new varieties and species can be brought forth to replace those being toppled by existing diseases, pests, or other environmental conditions.

Use the sun. Scientists recognize the sun as an "endless" energy source that can be used directly (solar heat) or indirectly (photosynthesis).

Engineers have made breakthroughs to exploit solar heat. Other scientists have only begun to tap the photosynthesis miracle which offers tremendous potential for increased food productivity. More about that under the next item . . .

Maximize protein energy. We need a bigger research effort on the two most important energy producing biochemical processes on earth: Photosynthesis and biological nitrogen fixation.

With photosynthesis, the plant traps energy from sunlight and uses this energy to grow. Scientists already are changing plants' shapes so more leaf area is exposed to the sun, thus improving their sunlight trapping system.

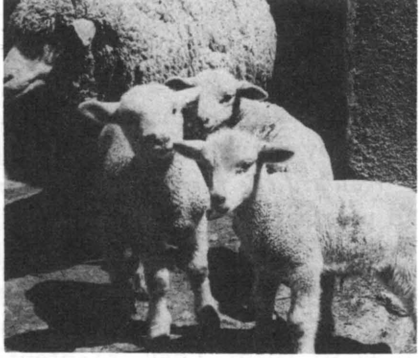
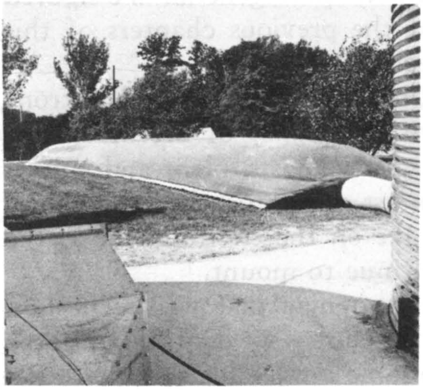
In the case of biological nitrogen fixation, soil microorganisms and certain plants work together to trap nitrogen from the air. Since fertilizer nitrogen is one of those limited resources, you can see the value of exploiting this *natural* nitrogen fixation process.

To state it bluntly, we must aim for the energy/protein limits in crop production.

This means new strategies for pest control, protective cultivation, multiple and intensive cropping, reduced tillage, using plant growth regulators, and so on. And we must circumvent environmental limitations, improve quality, enhance production and aid crop harvesting.

As part of building protein, we should upgrade it in plants and make better use of it in animals. Plant scientists are building essential amino acids (like lysine in corn and sorghum). Their job: upgrade plant protein so it can be substituted for animal protein in human diets.

Animal scientists are building protein by using nonprotein nitrogen (like urea or anhydrous ammonia) and combining it with corn silage and other roughages as a ration for ruminants (dairy cows, beef cattle, sheep). This way, livestock are less competitive with man for protein and energy, because the animal is

Top left, harvesting fish farm pond, Thailand. Top right, Corriedale ewe with her three lambs, Iran. Bottom, solar heat collector is tested for drying grain; this Ohio research is funded in part with a National Science Foundation grant administered by USDA.

converting what we cannot use into nutritious meat and milk.

Put it all together—for animals. That means exploiting their genetic potential (such things as multiple births and weight-gaining efficiency).

It also means building diets for optimum conversion of energy into meat, milk, and eggs.

Waste not. An ultimate goal is to recycle all plant and animal waste through the food chain—as an energy producer, animal feed and/or crop fertilizer.

Farm the waters. Since two-thirds of this planet is covered by water, it seems logical to investigate water fully as a food source.

Water—whether ocean or pond—could be a great protein producer, whether you're growing algae, lobsters, oysters, salmon, shrimp, catfish, or whatever.

Perfect the package. Efforts are being made to save some of the energy and billions of dollars spent each year to package products. Aim: recyclable packages. It may even mean reconstituting or eliminating conventional packages so the end product is in more readily consumable form. (Would you believe shell-less eggs?!)

Streamline distribution. We must cope with the food logistics problem—from production to processor to user. That means

building systems that minimize or eliminate the energy we now waste by moving too much bulk too far.

Reward the farmer. A major research priority is to give farmers an incentive for the job they do. These rewards, whether in the form of fair incomes and/or other benefits, will help us get and keep the quality of people we need in this profession.

There you have some of the ideas of future research priorities as we see them. They are intentionally quite general. We figured our colleagues had the benefit of the previous chapters of this book to get into more of the specifics.

Agricultural Experiment Stations must be in the forefront for designing systems to improve the quality of life of all our citizens. Economists, nutritionists, sociologists, plant and animal scientists, engineers and others must work together to achieve these ends. All need to keep an eye on the environment as the pressures of limited resources continue to mount.

As we talk of the future, we recognize that we are dealing in speculation. But we also know that unless we continually carry out research, we'll be forced into some intolerable situations. It's much less expensive to *act* to prevent these crises than to *react* once the damage is done.

That Delicate Balance

We recognize full well the importance of reassessing our national goals. We see the need for well balanced, interdisciplinary teams to screen, guide and project national programs and provide the support for sound agricultural research. We also see the need for maintaining a delicate balance between man and his environment as we carefully use energy, land, water and our nonrenewable minerals.

Looking back and considering the odds, the mere handful of publicly-supported agricultural research scientists have wrought miracles. There are only about 10,000 scientists at the 55 State Agricultural Experiment Stations and the U. S. Department of Agriculture. Yet, they deal with nearly 500 major commodities and resources—all subjected to a mind-boggling galaxy of problems and all deserving their full attention.

We think that team of agricultural scientists and farmers have done quite well, thank you. Our people are not only fed, but fed well with the world's most plentiful supply of nutritious, healthful food for the smallest part of their incomes anywhere in the world. But that's in the past. The tougher job lies ahead.

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Photography

Color pages carry no page numbers. For credit purposes, the first color page is I, and so on through XXXII. State organizations are listed for the most part only by the State's name.

Alabama (Auburn University), XII (upper left), XXIX (top), 151, 154, 155 (top right), 203 (top left)

Alaska, XVI (bottom inset)

American Agriculturist, 223

The American Farmer, 173, 249

Arizona, XXIV (top), 121, 209 (right)

Catherine Arnold, Louisiana State University, 259 (left)

Avco New Idea Farm Equipment, courtesy of *Michigan Farmer,* XXIV (bottom)

Baker Commodities, Inc., 276

Robert Bjork, USDA, XVIII (center three photos), 115, 206 (top two photos), 208, 227, 229 (left)

Tracy Borland, University of California (Davis), XXI (bottom right)

University of California (Berkeley), 6 (left), 30, 196 (top)

University of California (Davis), VI (left), XIV (top), XIX (top), 211 (two photos, third row), 275

University of California (Riverside), XXVI (top left), XXVI-XXVII (bottom), 36, 37, 171, 172, 173 (left), 175, 243, 302 (top, lower right)

California-Arizona Cotton, photo by Dan Weldon, XXI (top left)

California Tomato Growers Association, Inc., XVI-XVII (large photo)

Caterpillar Tractor Co., XXV

Jack K. Clark, University of California (Davis), XIII (bottom), XXX (all photos)

D. Vann Cleveland, University of Georgia, I, XXI (top right), 131, 165

Colonial Williamsburg, Inc., V (center)

Colorado, 76, 77, 282, 283

Connecticut (New Haven), XXVIII (top), 3, 5, 6 (right), 45, 67 (right), 109

Donald E. Didier, Louisiana, 270

Malcomb W. Emmons, Ohio State University, 291 (all photos)
The Farmer, painting by Mrs. George H. (Dorothea) Paul, IV (top)
Jim Ferguson, Nebraska, IX (upper left)
C. L. Fitch, Iowa State University, 211 (top two photos)
Florida, XV (top, center), XXVI (top right), XXVIII (bottom), XXIX (bottom)
Florida Grower and Rancher, photo by Chuck Woods, IFAS, Gainesville, Fla., XIV (bottom)
Food and Agriculture Organization of the United Nations (FAO), 349 (top two photos)
Frigidaire, 262 (bottom), 265 (right)
Georgia, 222
William G. Hart, ARS, Weslaco, Texas, XXXII (bottom)
Jack Hayes, 13, 179
R. W. Henderson, XIII (upper left)
Chuck Herron, USDA, XI (center, bottom), XXXI (top, bottom right)
Paul Hixon, Illinois, II-III, X (upper left), 7
Hoard's Dairyman, 147 (left)
Wolfgang Hoffman, Wisconsin, 60 (bottom)
Illinois, VII (both photos), X (bottom right), 216, 274, 297 (bottom right)
Iowa, 134 (left), 136, 137, 206 (bottom right), 296 (all photos)
Kansas Farmer, XXIII (top)
Kansas State Historical Society, 27 (courtesy of *Drovers Journal*), 140 (left)
John Kucharski, USDA, XXXII (top)
Otto R. Kunze, Texas A&M, XIII (upper right)
Raymond Lepine, Jr., Louisiana, 259 (right)
Maryland, 230
John McKinney, *Progressive Farmer,* 169
Michigan, XI (top)
Michigan Farmer, 113
Walter H. Miller, Williamsburg, Va., V (top)
Mississippi, XX (bottom)
Montana, IX (bottom, both photos)
J. R. Morris, University of Arkansas, XIII (center)
National Live Stock and Meat Board, XXII (bottom), XXIII (bottom)
National Wool Grower, 92
Nebraska, XXII (center), 271, 297 (top, bottom left)
Nebraska Farmer, VIII (bottom)
New Hampshire, 324 (bottom)
New York, 339 (above left)
C. B. Neiberding, 140 (right)
Ohio, X (center left), XX (top), XXIV (center left), XXXI (bottom left), 32, 101, 209 (left), 262 (left), 265 (left), 349 (bottom)
Oklahoma, 67 (left), 71, 72 (left)
Oregon, 83, 199 (right), 293
Pennsylvania, 118, 123, 146, 163 (right), 195, 196 (bottom left), 327 (both photos)
Plains Cooperative Oil Mill, XVII (inset)
Progressive Farmer, XV (bottom)
Progressive Grocer, 269 (top right)
Carl Purcell, AID, VIII (top), 346 (left)
Purdue University, 42 (left), 43
Rutgers University, 60 (top), 87, 346 (right)
R. K. Showalter, Florida, XVI (top inset)
South Carolina (Clemson University), XVIII (top)
South Dakota, 185
Sperry-New Holland, 203 (top right)
Perry Struse, X (bottom), XXIV (center right)
Tennessee, XVIII (bottom)
Texas, VI (right, both photos), XXII (top)
Texas Farmer-Stockman, 163 (left)
Today's Farmer, 134 (right)
Utah, 246 (left)
Wallaces Farmer, photo by Robert Dunaway, XIX (bottom)
Fred Ward, for USDA, XXI (bottom left)
David F. Warren, 65, 147 (right)
Washington State, 56 (left), 72 (right), 160 (right), 163 (top), 199 (left), 238 (top), 241, 339 (above right), 353
Washington State Apple Commission, XII (upper right)
Wisconsin, 129, 295, 325 (right)
George Yates, *Milwaukee Journal,* 49

Index

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